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## Description

## BACKGROUND OF THE INVENTION

## I. Field of the Invention

[0001] The present invention relates to data communication. More particularly, the present invention relates to a method and apparatus for high rate packet data transmission.

## II. Description of the Related Art

[0002] A modern day communication system is required to support a variety of applications. One such system is a code division multiple access (CDMA) system which conforms to the IS-95 standard. The CDMA system allows for voice and data communications between users over a terrestrial radio link. The use of CDMA techniques in a multiple access communication system is disclosed in U.S. Patent No. 5,103,459, entitled "SPREAD SPECTRUM MULTIPLE ACCESS COMMUNICATION SYSTEM USING SATELLITE OR TERRESTRIAL REPEATERS", and U.S. Patent No. 5,103,459, entitled "SYSTEM AND METHOD FOR GENERATING WAVEFORMS IN A CDMA CELLULAR TELEPHONE SYSTEM", both assigned to the assignee of the present invention.

[0003] In this specification, base station refers to the hardware with which the mobile stations communicate. The term "base station" may also refer to the hardware or the geographic coverage area, depending on the context in which the term is used. A sector of a cell is a partition of a cell. Because a sector of a CDMA system has the attributes of a cell, the teachings of the present invention can be readily extended to sectors.

[0004] In the CDMA system, communications between users are conducted through one or more base stations. A first user on one mobile station communicates to a second user on a second mobile station by transmitting data to a base station over a forward link and receiving data from the base station over a reverse link. The base station receives the data and can route the data to another base station. The data is transmitted on the forward link of the same base station, or a second base station, to the second user. The forward link refers to transmission from the base station to a mobile station and the reverse link refers to transmission from the mobile station to a base station. In the forward link and the reverse link are allocated different frequencies.

[0005] The mobile station communicates with at least one base station during a communication. CDMA mobile stations are capable of communicating with multiple base stations simultaneously during soft handoff. Soft handoff is the process of establishing a link with a new base station before breaking the link with the previous base station. This minimizes the probability of dropped calls. The method and system for providing a communication with multiple base stations through more than one base station during the soft handoff process are disclosed in U.S. Patent No. 5,103,459, entitled "MOBILE ASSISTED SOFT HANDOFF IN A CDMA CELLULAR TELEPHONE SYSTEM," assigned to the assignee of the present invention. Softer handoff is the process whereby the communication occurs over multiple base stations serviced by the same base station. The process of softer handoff is described in detail in copending U.S. Patent Application Serial No. 08/763,498, entitled "METHOD AND APPARATUS FOR PERFORMING HANDOFF BETWEEN SECTORS OF A COMMON BASE STATION", filed December 11, 1996, assigned to the assignee of the present invention.

[0006] Given the growing demand for wireless data applications, the need for very efficient wireless communication systems has become increasingly significant. A CDMA system is capable of transmitting traffic data and voice data over the forward and reverse links. A method for transmitting traffic data in code channel frames is disclosed in detail in U.S. Patent No. 5/504,773, entitled "METHOD AND APPARATUS FOR THE FORMATTING OF DATA IN A CDMA SYSTEM", assigned to the assignee of the present invention. In accordance with the present invention, traffic data or voice data is partitioned into code channel frames which are 20 msec wide with data rates as high as 1.92 Mc/sec.

[0007] A significant difference between voice services and data services is the fact that the former have fixed delay requirements. Typically, the delay between speech frames must be less than 100 msec. In contrast, the data delay can become a variable parameter used to optimize the efficiency of the communication system. Specifically, more efficient error correcting coding techniques which require significantly more delay than can be tolerated by voice services can be utilized. An exemplary efficient coding scheme for data services is disclosed in U.S. Patent Application Serial No. 08/743,688, entitled "SOFT DECISION OUTPUT DECODER FOR DECODING CONVOLUTIONALLY ENCODED CODEWORDS", filed November 6, 1996, assigned to the assignee of the present invention.

[0008] Another significant difference between voice services and data services is that the former require a common grade of service (GOS) for all users. Typically, for digital systems providing voice services, a fixed and equal transmission rate for all users and a maximum tolerable value for the error rate are required. In contrast, for data services, the GOS can be different from user to user and can be a parameter used to optimize the overall efficiency of the data communication system. The GOS of a data communication system is a function of the user's requirements.

as the total delay incurred in the transfer of a predetermined amount of data, hereinafter referred to as the total delay. [0009] Yet another significant difference between voice services and data services is that the former requires a dedicated communication link which, in the exemplary CDMA communication system, is provided by soft handoff. This results in redundant transmissions from two or more base stations to improve reliability. However, this is not required for data transmission because the data packets received in error can be retransmitted. [0010] The parameters which measure the quality and effectiveness of a data communication system are the transmission delay required to transfer a data packet and the average throughput rate of the system. The transmission delay does not have the same impact in data communication as it does for voice communication, but it is important for measuring the quality of the data communication system. The average throughput rate is a measure of the data transmission capability of the communication system. [0011] It is well known that in cellular systems the carrier-to-interference ratio C/I of any given user is a function of the location of the user within the coverage area. In order to maintain a given level of performance, FDMA systems resort to frequency reuse techniques, i.e. not all frequency channels and/or time slots are used by every base station. In a CDMA system, the same frequency allocation is reused in every cell of the system to improve the overall efficiency. The C/I that any given user's mobile station achieves determines the information rate supported for this particular link from the base station to the user's mobile station. Given the error correction method used for the transmission, which the present invention seeks to optimize for, a given level of performance is achieved at a corresponding level of C/I. For idealized cellular systems with regular cell layouts and utilizing a common frequency in every cell, the distribution of C/I achieved with soft handoff can be calculated.

[0012] The C/I achieved by any given user is a function of the path loss, which for terrestrial cellular systems is proportional to  $r^{-\alpha}$ , where  $r$  is the distance to the radiating source. Furthermore, the path loss is subject to random variations due to man-made or natural obstructions within the path of the radio wave. These random variations are modeled as a lognormal shadowing random process with a standard deviation of 8 dB. The resulting C/I distribution for an ideal hexagonal cellular layout with omnidirectional base stations and a two-ray propagation law, and shadowing process with 8 dB standard deviation is shown in Fig. 10.

[0013] The obtained C/I distribution can only be achieved if, at any instant in time and at any location, the mobile station is served by the best base station which is defined as that achieving the largest C/I value. The physical distance to each base station. Because of the random nature of the path loss as described above, the base station with the largest C/I value can be one which is other than the minimum physical distance from the mobile station. In contrast, if a mobile station was to communicate only via the base station of minimum distance, the C/I would be degraded. It is therefore beneficial for mobile stations to communicate to and from the best serving base station at all times, thereby achieving the optimum C/I value. It can also be observed that the range of values of C/I in the above idealized model and as shown in FIG. 10, is such that the difference between the highest and lowest values can be as large as 10,000. In practical implementation the range is typically limited to approximately 100. It is therefore possible for a CDMA base station to serve mobile stations with information bit rates that differ by as much as a factor of 100, since the following relationship holds:

$$R_b = W \frac{(C/I)}{(E_b/I_0)} \quad (1)$$

where  $R_b$  represents the information rate to a particular mobile station,  $W$  is the total bandwidth of the spectrum signal,  $E_b/I_0$  is the energy per bit over interference density required to achieve a given level of performance. For instance, if the spread spectrum signal occupies a bandwidth  $W$  of 1.2288 MHz and reliable communication requires an average  $E_b/I_0$  equal to 3 dB, then a mobile station which achieves a C/I value of 3 dB to the best serving base station can communicate at a data rate as high as 1.2288 Mbps. On the other hand, if a mobile station is subject to high interference from adjacent base stations and can only achieve a C/I of -7 dB, reliable communication requires a data rate at a rate greater than 122.88 Kbps. A communication system designed to optimize the average throughput rate must attempt to serve each remote user from the best serving base station and at the highest possible data rate that the user can reliably support. The data communication system of the present invention exploits the characteristics of the CDMA system and optimizes the data throughput from the CDMA base stations to the mobile stations.

[0014] From the US patent 6,134,220, a method of adapting the air interface in a mobile radio system is known. In this system, base transceiver station, mobile station and transmission mode are known. For adaptation of the system, two separate analyses of transmission quality are carried out for each transmission direction. In each transmission direction, one of the coding modes is selected in accordance with the corresponding transmission quality.

analysis.

[0015] From the US patent 5,638,412, a method and apparatus for negotiating service configuration in a communication system is known. The service configuration comprises data rates, frame formats and type.

[0016] WO 97/09810 relates to a method and apparatus for multirate data communication. In one embodiment, a system is provided for multirate communications allowing for different data rates for each data unit. Both data units from different mobile units and from the same mobile unit. A sending unit preferably determines the rate at which to start communications, and monitors, for example by use of an RSSI detector, the rate should be changed. A rate adjustor implements the change, and can make changes as frequently as desired.

# SUMMARY OF THE INVENTION

[0017] The invention is defined in the independent claims 1, 7, 19, 31.

[0018] The present invention is a novel and improved method and apparatus for high rate packet data communication in a CDMA system. The present invention improves the efficiency of a CDMA system by providing for simultaneous transmission of data on the forward and reverse links. Each mobile station communicates with one or more base stations. The mobile station monitors the control channels for the duration of the communication with the base stations. The mobile station can be used by the base stations to transmit small amounts of data, paging messages addressed to a specific mobile station, and broadcast messages to all mobile stations. The paging message informs the mobile station that the base station has a large amount of data to transmit to the mobile station.

[0019] It is an object of the present invention to improve utilization of the forward and reverse links in a communication system. Upon receipt of the paging messages from one or more base stations, the mobile station measures the signal-to-interference ratio (C/I) of the forward link signals (e.g. the forward link pilot signals) at every time slot and selects the best base station using a set of parameters which can comprise the present measurements. In an exemplary embodiment which is not part of the invention, at every time slot, the mobile station transmits to the selected base station on a dedicated data request (DRC) channel a request for the highest data rate which the measured C/I can reliably support. The selected base station transmits data to the mobile station at a data rate not exceeding the data rate received from the mobile station on the DRC channel. By selecting the best base station at every time slot, improved throughput and transmission delay are achieved.

[0020] It is another exemplary embodiment which is not part of the present invention to improve the efficiency of transmitting from the selected base station at the peak transmit power for the duration of one or more time slots. The mobile station at the data rate requested by the mobile station. In the exemplary CDMA communication system, the base stations operate at a predetermined backoff (e.g. 3 dB) from the available transmit power to account for fading in usage. Thus, the average transmit power is half of the peak power. However, in the present invention, high speed data transmissions are scheduled and power is typically not shared (e.g., among transmissions) but is reserved to backoff from the available peak transmit power.

[0021] It is yet another exemplary embodiment which is not part of the present invention to enhance the efficiency of allowing the base stations to transmit data packets to each mobile station for a variable number of time slots. The ability to transmit from different base stations from time slot to time slot allows the data communication system to quickly adopt to changes in the operating environment. In addition, the ability to transmit data in non-contiguous time slots is possible in the present invention because of the use of sequence numbers to identify data units within a data packet.

[0022] It is yet another exemplary embodiment which is not part of the present invention to improve the efficiency of forwarding the data packets addressed to a specific mobile station from a central controller to a set of base stations which are members of the active set of the mobile station. In the present invention, data transmission can occur from any base station in the active set of the mobile station at each time slot. Since each base station comprises a portion of the data to be transmitted to the mobile station, efficient forward link transmission can occur with multiple base stations.

[0023] It is yet another exemplary embodiment which is not part of the present invention to provide a mechanism for data units received in error. In the exemplary embodiment, each data packet comprises a sequence number of data units, with each data unit identified by a sequence number. Upon incorrect receipt of data units, the mobile station sends a negative acknowledgment (NACK) on the reverse link data channel indicating the sequence numbers of the missing data units for retransmission from the base station. The base station receives the NACK message and can retransmit the data units received in error.

[0024] It is yet another exemplary embodiment which is not part of the present invention for the mobile station to select the best base station candidates for communication based on the procedure described in U.S. Patent No. 08/790,497, entitled "METHOD AND APPARATUS FOR PERFORMING SOFT HANDOFF IN A WIRELESS COMMUNICATION SYSTEM", filed January 29, 1997, assigned to the assignee of the present invention. In one embodiment, the base station can be added to the active set of the mobile station if the received signal strength is above a threshold.

predetermined add threshold and dropped from the active set if the pilot signal is below a predetermined threshold. In the alternative embodiment, the base station can be added to the active set if the additional energy (e.g. as measured by the pilot signal) and the energy of the base stations already in the active set is above a predetermined threshold. Using this alternative embodiment, a base station which transmitted energy comprises an amount of the total received energy at the mobile station is not added to the active set.

[0025] It is yet another exemplary embodiment which is not part of the present invention for the mobile station to transmit the data rate requests on the DRC channel in a manner such that only the selected base station transmits the data rate requests. The base station in communication with the mobile station is able to distinguish the DRC messages, the DRC message for the forward link transmission at any given time slot is from the selected base station. In the alternative embodiment, each base station in communication with the mobile station is assigned a unique Walsh code. The mobile station receives the DRC message with the Walsh code corresponding to the selected base station. Other codes can be used for the DRC messages, although orthogonal codes are typically utilized and Walsh codes are preferred.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0026] The features, objects, and advantages of the present invention will become more apparent from the following description set forth below when taken in conjunction with the drawings in which like reference numerals correspondingly throughout and wherein:

FIG. 1 is a diagram of a data communication system of the present invention comprising a plurality of base stations and a plurality of mobile stations.

FIG. 2 is an exemplary block diagram of the subsystems of the data communication system of the present invention.

FIGS. 3A-3B are block diagrams of the exemplary forward link architecture of the present invention.

FIG. 4A is a diagram of the exemplary forward link frame structure of the present invention;

FIGS. 4B-4C are diagrams of the exemplary forward traffic channel and power control channel, respectively;

FIG. 4D is a diagram of the punctured packet of the present invention;

FIGS. 4E-4G are diagrams of the two exemplary data packet formats and the control channel capsule;

FIG. 5 is an exemplary timing diagram showing the high rate packet transmission on the forward link;

FIG. 6 is a block diagram of the exemplary reverse link architecture of the present invention;

FIG. 7A is a diagram of the exemplary reverse link frame structure of the present invention;

FIGS. 7B is a diagram of the exemplary reverse link access channel;

FIG. 8 is an exemplary timing diagram showing the high rate data transmission on the reverse link;

FIG. 9 is an exemplary state diagram showing the transitions between the various operating states of the mobile station; and

FIG. 10 is a diagram of the cumulative distribution function (CDF) of the C/I distribution in an exemplary system layout.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0027] In accordance with the exemplary embodiment of the data communication system of the present invention, forward link data transmission occurs from one base station to one mobile station (see FIG. 1) at a data rate which can be supported by the forward link and the system. Reverse link data transmission occurs from one mobile station to one or more base stations. The calculation of the maximum data rate for forward link transmission is described in detail below. Data is partitioned into data packets, with each data packet being transmitted over more time slots (or slots). At each time slot, the base station can direct data transmission to any one of the mobile stations in communication with the base station..

[0028] Initially, the mobile station establishes communication with a base station using a predetermined procedure. In this connected state, the mobile station can receive data and control messages from the base station and is able to transmit data and control messages to the base station. The mobile station then monitors the forward link transmissions from the base stations in the active set of the mobile station. The active set contains the base stations in communication with the mobile station. Specifically, the mobile station monitors the signal-to-interference ratio (C/I) of the forward link pilot from the base stations in the active set, as received at the mobile station. If the pilot signal is above a predetermined add threshold or below a predetermined drop threshold, the mobile station adds or drops this to the base station. Subsequent messages from the base station direct the mobile station to a particular state (station) to or from its active set, respectively. The various operating states of the mobile station are described below.

[0029] If there is no data to send, the mobile station returns to an idle state and discontinues transmitting information to the base station. While the mobile station is in the idle state, the mobile station monitors the forward link channel from one or more base stations in the active set for paging messages.

[0030] If there is data to be transmitted to the mobile station, the data is sent by a central controller in the active set and stored in a queue at each base station. A paging message is then sent by one of the base stations to the mobile station on the respective control channels. The base station may transmit all such data at the same time across several base stations in order to ensure reception even when the mobile station is in a fading area between base stations. The mobile station demodulates and decodes the signals on one or more control channels to receive the paging messages.

[0031] Upon decoding the paging messages, and for each time slot until the data transmission is complete, the mobile station measures the C/I of the forward link signals from the base stations in the active set, as well as the C/I of the reverse link signals from the mobile station. The C/I of the forward link signals can be obtained by measuring the respective pilot signals. The mobile station then selects the best base station based on a set of parameters. The set of parameters can comprise the C/I of the previous C/I measurements and the data rate or packet rate. For example, the best base station can be selected based on the largest C/I measurement. The mobile station then identifies the best base station and transmits a selected base station a data request message (hereinafter referred to as the DRC message) on the data channel (hereinafter referred to as the DRC channel). In an embodiment which is not part of the invention, the DRC message can contain the requested data rate. Alternatively, in an embodiment which is part of the invention, the DRC message contains an indication of the quality of the forward link channel (e.g., the C/I measurement) and the requested data rate or packet rate. In the exemplary embodiment, the mobile station can direct the transmission of data to a specific base station by the use of a Walsh code which uniquely identifies the base station. The data symbols are exclusively OR'ed (XOR) with the unique Walsh code. Since each base station in the active set is identified by a unique Walsh code, only the selected base station which performs the XOR operation as that performed by the mobile station, with the correct Walsh code, can correctly decode the DRC message. The base station uses the rate control information from each mobile station to efficiently transmit forward data at the highest possible rate.

[0032] At each time slot, the base station can select any of the paged mobile stations for data transmission. The base station then determines the data rate at which to transmit the data to the selected mobile station based on the most recent value of the DRC message received from the mobile station. Additionally, the base station can direct the transmission to a particular mobile station by using a spreading code which is unique to that mobile station. In an exemplary embodiment, this spreading code is the long pseudo noise (PN) code 955, which is standard defined by IS-95.

[0033] The mobile station, for which the data packet is intended, receives the data transmission and decodes the data packet. Each data packet comprises a plurality of data units. In the exemplary embodiment, a data unit is 480 bits of information bits, although different data unit sizes can be defined and are within the scope of the invention. In the exemplary embodiment, each data unit is associated with a sequence number and the mobile station can identify either missed or duplicative transmissions. In such events, the mobile stations communicate with the base station over the data channel the sequence numbers of the missing data units. The base station controllers, which receive the messages from the mobile stations, then indicate to all base stations communicating with this particular mobile station which data units were not received by the mobile station. The base stations then schedule a retransmission of the missing data units.

[0034] Each mobile station in the data communication system can communicate with multiple base stations in the forward and reverse link. In the exemplary embodiment, the data communication system of the present invention supports soft and softer handoff on the reverse link for several reasons. First, soft handoff does not consume additional power on the reverse link but rather allows the mobile stations to transmit data at the minimum power level while maintaining the quality of the base stations can reliably decode the data. Second, reception of the reverse link signals from multiple base stations increases the reliability of the transmission and only requires additional hardware at the base station.

[0035] In an exemplary embodiment which is not part of the invention, the forward link capacity of the data communication system of the present invention is determined by the rate requests of the mobile stations. Additionally, the forward link capacity can be achieved by using directional antennas and/or adaptive spatial filters. An exemplary apparatus for providing directional transmissions are disclosed in copending U.S. Patent Application No. 08/925,521, entitled "METHOD AND APPARATUS FOR DETERMINING THE TRANSMISSION DATA RATE IN A MULTISITE COMMUNICATION SYSTEM", filed December 20, 1995, and U.S. Patent Application Serial No. 08/925,522, entitled "METHOD AND APPARATUS FOR PROVIDING ORTHOGONAL SPOT BEAMS, SECTORS, AND PICOCELLS", filed September 8, 1997, both assigned to the assignee of the present invention..

## I. System Description

[0036] Referring to the figures, FIG. 1 represents the exemplary data communication system of the present invention which comprises multiple base stations. Each cell is serviced by a corresponding base station. Mobile stations 106 are dispersed throughout the data communication system. In the exemplary embodiment, each of the mobile stations communicates with at most one base station in the forward link at each time slot but can be in communication with multiple base stations in the reverse link.

one or more base stations on the reverse link, depending on whether the mobile station is in a receive or transmit mode. For example, base station 14a transmits data exclusively to mobile station 16a, base station 14b transmits data exclusively to mobile station 16b, and base station 14c transmits data exclusively to mobile station 16c. In FIG. 1, the solid line with the arrow indicates a data transmission from base station 14a to mobile station 16a. A broken line with the arrow indicates that mobile station 16a is receiving the pilot signal, but no data transmission from base station 14a. The reverse link communication is not shown in FIG. 1 for simplicity.

[0037] As shown by FIG. 1, each base station 14a, 14b, and 14c transmits data to one mobile station 16a, 16b, and 16c, respectively. Mobile stations 16a, 16b, and 16c, especially those located near a cell boundary, can receive the pilot signals from multiple base stations 14a, 14b, and 14c. If the pilot signal is above a predetermined threshold, mobile station 16a is added to the active set of mobile stations. In the exemplary embodiment, mobile station 16a receives data transmission from zero or one member of the active set.

[0038] A block diagram illustrating the basic subsystems of the data communication system of the present invention is shown in FIG. 2. Base station 10 interfaces with packet network 24 in PSTN 30, and all base stations 10 in the data communication system (only one base station is shown in FIG. 2 for simplicity). Base station 10 coordinates the communication between mobile station 16, a data communication system and other users connected to packet network 24 and PSTN 30. PSTN 30 interfaces with users through the standard telephone network (not shown in FIG. 2).

[0039] Base station controller 12 contains many selector elements, although only one is shown in FIG. 2 for simplicity. One selector element 14 is assigned to control the communication between one or more base stations 10 and one mobile station 16. If selector element 14 has not been assigned to mobile station 16, station controller 12 is informed of the need to page mobile station 16. Station controller 12 then directs base station 10 to page mobile station 16.

[0040] Data source 20 contains the data which is to be transmitted to mobile station 16. Data source 20 provides the data to packet network interface 22. Packet network interface 22 receives the data and routes the data to selector element 14. Selector element 14 sends the data to each base station 10 for communication with mobile station 16. Each base station 10 maintains data queue 40 which contains the data to be transmitted to mobile station 16.

[0041] In the exemplary embodiment, on the forward link, a data packet refers to a predetermined amount of data which is independent of the data rate. The data packet is formatted with other control and coding information. Data transmission occurs over multiple Walsh channels, the encoded packet is demultiplexed into parallel streams, each stream transmitted over one Walsh channel.

[0042] The data is sent, in data packets, from data channel element 42. For each data packet, channel element 42 inserts the necessary control fields. The data packet, control fields, frame check sequence, and tail bits comprise a formatted packet. Channel element 42 encodes one or more formatted packets and interleaves (or reorders) the symbols within the encoded packets. Next, the interleaved packet is scrambled by a scrambling sequence, covered with Walsh covers, and spread with the long PN code and the short PN spread code. The spread data is quadrature modulated, filtered, and amplified by a transmitter. The forward link signal is transmitted over the air through antenna 46 on the forward link.

[0043] At mobile station 16, the forward link signal is received by antenna 60 and routed to a receiver within front end 62. The receiver filters, amplifies, quadrature demodulates, and quantizes the signal. The digitized signal is then processed by a demodulator (DEMOD) 64 where it is despread with the long PN code and the short PN code. The demodulated data is then processed by a decoder 66 which performs the inverse of the signal processing functions, does channel equalization, interleaving, decoding, and frame check functions. The decoded data is provided to the data sink 68. The hardware, sink described above, supports transmissions of data, messaging, voice, video, and other communications over the forward link.

[0044] The system control and scheduling functions can be accomplished by many implementations. The channel scheduler 48 is dependent on whether a centralized or distributed scheduling is desired. For example, for distributed processing, channel scheduler 48 is located within each base station 10. Alternatively, for centralized processing, channel scheduler 48 is located within base station 10 and controller 12 is designed to coordinate the data transmissions of multiple base stations. Other implementations of the above described functions can be contemplated and are within the scope of the present invention.

[0045] As shown in FIG. 1, mobile stations 16 are dispersed throughout the data communication system and can be in communication with zero or one base station on the forward link. In the exemplary embodiment, channel scheduler 48 coordinates the forward link data transmissions of the mobile stations. In the exemplary embodiment, channel scheduler 48 connects to data queue 40 and channel element 42 within base station 10 and receives the queue size, which is indicative of the amount of data to transmit to mobile station 16, and the data rate. Channel scheduler 48 schedules high rate data transmission such that the system goals of maximum data throughput and minimum transmission delay are optimized.

[0046] In the exemplary embodiment, the data transmission is scheduled based in part on the quality of the forward link.

nication link. An exemplary communication system which selects the transmission rate based on the disclosed in U.S. Patent Application Serial No. 08/741,320, entitled "METHOD AND APPARATUS FOR HIGH SPEED DATA COMMUNICATIONS IN A CELLULAR ENVIRONMENT", filed September 11, 1996, assigned to the assignee of the present invention. In the present invention, the scheduling of the data communication on additional considerations such as the GOS of the user, the queue size, the type of data, the amount experienced, and the error rate of the data transmission. These considerations are described in Application No. 08/798,951, entitled "METHOD AND APPARATUS FOR FORWARD LINK RATE SCHEDULING", filed February 11, 1997, and U.S. Patent Application Serial No. \_\_\_\_\_, entitled "METHOD AND APPARATUS FOR REVERSE LINK RATE SCHEDULING", filed August 20, 1997, both are assigned to the assignee of the present invention. Other factors can be considered in scheduling data transmissions and are within the scope of the present invention.

[0047] The data communication system of the present invention supports data and message transmission on the reverse link. Within mobile station 10, a controller 12 processes the data or message transmission by routing the data or message to encoder 22. Controller 12 can be implemented in a microcontroller, a microprocessor, a digital signal processing (DSP) chip, or an ASIC programmed to perform the function as described herein.

[0048] In the exemplary embodiment, encoder 22 encodes the message consistent with the Blank and Burst signaling format described in the aforementioned U.S. Patent No. 5,250,477. Encoder 22 appends a set of CRC bits, appends a set of code tail bits, encodes the data and appended bits, and reorders the encoded data. The interleaved data is provided to modulator (MOD) 74.

[0049] Modulator 74 can be implemented in many embodiments. In the exemplary embodiment (see FIG. 1), the interleaved data is covered with Walsh codes, spread with a long PN code, and further spread with a Barker code. The spread data is provided to a transmitter 60. The transmitter 60 modulates, filters, amplifies, and transmits the reverse link signal over the air, through reverse link 5.

[0050] In the exemplary embodiment, mobile station 10 transmits the reverse link data in accordance with a long PN code. Each reverse link channel is defined in accordance with the temporal offset of a common long PN code. Two differing offsets the resulting modulation sequences are uncorrelated. The offset is determined in accordance with a unique numerical identification of mobile station 10, which is an exemplary embodiment of the IS-95 mobile station's mobile station specific identification number. Thus, transmission of the reverse link data is uncorrelated reverse link channel determined in accordance with its unique electronic serial number.

[0051] At base station 40, the reverse link signal is received by antenna 46 and provided to RF unit 44. RF unit 44 filters, amplifies, demodulates, and quantizes the signal and provides the digitized signal to channel element 42. Channel element 42 despreads the digitized signal with the short PN codes and the long PN code. Channel element 42 also performs the Walsh code deconvolution and pilot and DRC extraction. Channel element 42 then decodes the interleaved data, decodes the interleaved data, and performs the CRC check function. The decoded data, e.g., message, is provided to selector 48. Selector 48 routes the data and message to the appropriate destination. Channel element 42 may also forward a quality indicator to selector 48 indicating the condition of the received data packet.

[0052] In the exemplary embodiment, mobile station 10 is in one of three operating states. An exemplary state diagram showing the transitions between the various operating states of mobile station 10 is shown in FIG. 2. In the access state 902, mobile station 10 sends access probes and waits for channel assignment by base station 40. Channel assignment comprises allocation of resources, such as a power control channel and frequency allocation. Mobile station 10 can transition from the access state 902 to the connected state 904 if mobile station 10 is paged and alerted to an upcoming data transmission, or if mobile station 10 transmits data on the reverse link. In the connected state 904, mobile station 10 exchanges (e.g., transmits or receives) data and performs handoff operations. Upon completion of the handoff procedure, mobile station 10 transitions from the connected state 904 to the idle state 906. Mobile station 10 can also transition from the access state 902 to the idle state 906 upon being rejected of a connection with base station 40. In the idle state 906, mobile station 10 listens to overhead and paging messages by receiving and decoding messages on the forward control channel and performs idle handoff procedure. Mobile station 10 can transition to the access state 902 by initiating the procedure. The state diagram shown in FIG. 9 is only an exemplary state definition and is not intended to be a limitation. Other state diagrams can also be utilized and are within the scope of the present invention.

## II. Forward Link Data Transmission

[0053] In the exemplary embodiment, the initiation of a communication between mobile station 10 and base station 40 occurs in a similar manner as that for the CDMA system. After completion of the call set up, mobile station 10 transmits the control channel for paging messages. While in the connected state 904, mobile station 10 transmits the pilot signal on the reverse link.

[0054] An exemplary flow diagram of the forward link high rate data transmission of the present invention is shown in FIG. 3.



FIG. 5. If base station 4 has data to transmit to mobile station 6, base station 4 sends a paging message addressed to mobile station 6 on the control channel 502. The paging message can be sent from one or multiple base stations 4, depending on the handoff state of mobile station 6. Upon reception of the paging message, mobile station 6 begins the C/I measurement process 504. The C/I of the forward link signal is calculated from one or a combination of the methods described below. Mobile station 6 selects a requested data rate based on the best C/I measurement. Base station 4 transmits a DRC message on the DRC channel 504. Block [0055] Within the same time slot, base station 4 receives the DRC message at 508. If the next time slot is available for data transmission, base station 4 transmits data to mobile station 6 at the requested data rate 510. Mobile station 6 receives the data transmission 512. If the next time slot is available, transmission of the remainder of the packet 514. Mobile station 6 receives the data transmission 516. Block [0056] In the present invention, mobile station 6 communicates with one or more base stations 4 simultaneously. The actions taken by mobile station 6 depend on whether mobile station 6 is not in soft handoff. These two cases are discussed separately below.

### III. No Handoff Case

Block [0057] In the no handoff case, mobile station 6 communicates with one base station 4. Referring to FIG. 2, the data destined for a particular mobile station 6 is provided to selector 14. Element 14 has been assigned to control the communication with that mobile station 6. Selector 14 forwards the data to data queue 40 in base station 4. Base station 4 queues the data and transmits a paging message on the control channel 502. Base station 4 transmits the reverse link DRC channel for DRC messages from mobile station 6. If a signal is detected on the DRC channel, base station 4 can retransmit the paging message until the DRC message is detected. After a predetermined number of retransmission attempts, base station 4 terminates the process and initiates a call with mobile station 6. Block [0058] In the exemplary embodiment which is not part of the invention, mobile station 6 requests data rate, in the form of a DRC message, to base station 4 on the DRC channel. In the alternative embodiment, mobile station 6 transmits an indication of the quality of the forward link channel (e.g., the C/I measurement). In the exemplary embodiment, the DRC message is decoded with soft decisions by base station 4. In the alternative embodiment, the DRC message is transmitted within the first half of each time slot. Base station 4 receives half of the time slot to decode the DRC message and configure the hardware for data transmission at the next time slot, if that time slot is available for data transmission. If the next time slot is not available, base station 4 waits for the next available time slot and continues to monitor the DRC channel for DRC messages.

Block [0059] In the first embodiment which is not part of the invention, base station 4 transmits the requested data rate. This embodiment confers to mobile station 6 the important decision of selecting the data rate. Always transmitting the requested data rate has the advantage that mobile station 6 does not have to expect. Thus, mobile station 6 only demodulates and decodes the traffic channel in accordance with the requested data rate. Base station 4 does not have to transmit a message to mobile station 6 indicating which data rate is being used by base station 4.

Block [0060] In the first embodiment which is not part of the invention, after reception of the paging message, mobile station 6 continuously attempts to demodulate the data at the requested data rate. Mobile station 6 receives the forward traffic channel and provides the soft decision symbols to the decoder. The decoder decodes the symbols and provides the frame check on the decoded packet to determine whether the packet was received correctly. If the received in error or if the packet was directed for another mobile station, it would indicate a packet error. Alternatively in the first embodiment, mobile station 6 demodulates the data on a slot by slot basis. In the exemplary embodiment, mobile station 6 is able to determine whether a data transmission is directed for it based on the frame check which is incorporated within each transmitted data packet, as described below. When mobile station 6 receives the decoding process if it is determined that the transmission is directed for another mobile station, mobile station 6 transmits a negative acknowledgment (NACK) message to base station 4 to acknowledge the incorrect reception of the data units. Upon receipt of the NACK message, the data units received in error are retransmitted.

Block [0061] The transmission of the NACK messages can be implemented in a manner similar to the transmission of the error indicator bit (EIB) in the CDMA system. The implementation and use of EIB transmission are described in U.S. Patent No. 5,568,483, entitled "METHOD AND APPARATUS FOR THE FORMATTING OF DATA FOR TRANSMISSION", assigned to the assignee of the present invention. Alternatively, NACK can be transmitted via the reverse link. Block [0062] In the second embodiment, the data rate is determined by base station 4 from mobile station 6. Mobile station 6 performs the C/I measurement and transmits an indication of the link quality (e.g., the C/I measurement) to base station 4. Base station 4 can adjust the requested data rate based on the resources available to base station 4, such as the queue size and the available transmit power. The adjusted data rate can be transmitted prior to or concurrent with data transmission at the adjusted data rate, or can be implied in the data transmission packets. In the first case, wherein mobile station 6 receives the adjusted data rate before the data transmission

station 6 demodulates and decodes the received packet in the manner described in the first embodiment case, wherein the adjusted data rate is transmitted to mobile station 6 with the data transmission, mobile station 6 can demodulate the forward traffic channel and store the demodulated data. Upon receipt of rate, mobile station 6 decodes the data in accordance with the adjusted data rate. And in the third case, adjusted data rate is implied in the encoded data packet, mobile station 6 demodulates and decodes all candidate rates and determine a posteriori the transmit rate for selection of the decoded data. The method and apparatus for rate determination are described in detail in U.S. Patent Application Serial No. 08/730,863, entitled "APPARATUS FOR DETERMINING THE RATE OF RECEIVED DATA IN A VARIABLE RATE COMMUNICATION SYSTEM", filed October 18, 1996, and Patent Application Serial No. PA436, also entitled "METHOD AND APPARATUS FOR DETERMINING THE RATE OF RECEIVED DATA IN A VARIABLE RATE COMMUNICATION SYSTEM", filed \_\_\_\_\_, both assigned to the assignee of the present invention. For all cases described, station 6 transmits a NACK message as described above if the outcome of the frame check is negative. [0063] The discussion hereinafter is based on the first embodiment which is not part of the invention. Station 6 transmits to base station 4 a DRC message indicative of the requested data rate, except as otherwise stated. However, the inventive concept described herein is equally applicable to the second embodiment wherein station 6 transmits an indication of the link quality to base station 4.

#### IV. Handoff Case

[0064] In the handoff case, mobile station 6 communicates with multiple base stations 4 via a reverse link. In the exemplary embodiment, data transmission on the forward link to a particular mobile station 6 is from a particular base station 4. However, mobile station 6 simultaneously receives the pilot signals from multiple base stations 4. When the measurement of a base station 4 is above a predetermined threshold, the base station 4 is added to the active set of mobile station 6. During the soft handoff direction message, the new base station 4 is added to the active set. power control (RPC) Walsh channel which is described below. Each base station 4 with mobile station 6 monitors the reverse link transmission and sends an RPC bit on their respective RPC Walsh channels. [0065] Referring to FIG. 2, selector 14 is assigned to control the communication with mobile station 6 and forward the data to all base stations 4 in the active set of mobile station 6. All base stations 4 in the active set receive data from selector element 14. Selector 14 transmits a paging message to mobile station 6 on their respective control channels. When mobile station 6 is in the connected state, mobile station 6 performs two functions. First, mobile station 6 selects the best base station 4 based on a set of parameters which can be the best C/I measurement, the mobile station 6's data rate corresponding to the C/I measurement and transmits a DRC message to the selected base station 4. The selected base station 4 can direct transmission of the DRC message to a particular base station 4. Then the DRC message with the Walsh cover assigned to that particular base station 4 is transmitted. Mobile station 6 then attempts to demodulate the forward link signal in accordance with the requested data rate at each subsequent time slot. [0066] After transmitting the paging messages, all base stations 4 in the active set monitor the DRC channel for a DRC message from mobile station 6. Again, because the DRC message is covered with a Walsh code, the selected base station 4, assigned with the identical Walsh cover is able to discover the DRC message. Upon receiving the DRC message, the selected base station 4 transmits data to mobile station 6 at the next available time slots. [0067] In the exemplary embodiment, base station 4 transmits data in packets comprising a plurality of data units. If the requested data rate to mobile station 6 is incorrectly received, by a NACK message, the data units are retransmitted on the reverse link to all base stations 4 in the active set. In the exemplary embodiment, the NACK message is demodulated and decoded by base station 4 and forwarded to selector 14 for processing. Upon processing of the NACK message, the data units are retransmitted using the procedure as described above. In the exemplary embodiment, selector 14 combines the NACK signals received from all base stations 4 in the active set. Selector 14 then sends the NACK message to all base stations 4 in the active set. [0068] In the exemplary embodiment, mobile station 6 can detect changes in the best C/I measurement and dynamically request data transmissions from different base stations 4 in the next time slot to improve efficiency. In the exemplary embodiment, since data transmission occurs from only one base station 4 in one time slot, other base stations 4 in the active set may not be aware which data units, if any, has been transmitted. In the exemplary embodiment, the transmitting base station 4 informs selector element 14 of the data transmission. Selector element 14 then sends a message to all base stations 4 in the active set. In the exemplary embodiment, the transmitted data is presumed to have been correctly received by mobile station 6. Therefore, if mobile station 6 requests data transmission from a different base station 4 in the active set, the new base station 4 transmits the remaining data units. In the exemplary embodiment, the new base station 4 transmits in accordance with the last transmission update from selector 14. Alternatively, the new base station 4 selects the next data units to transmit using predictive schemes such as the average transmission rate and prior updates from the selected base station 4 to minimize duplicative retransmissions of the same data units by multiple base stations 4 in the active set.

loss in efficiency. If a prior transmission was received in error, base stations send data units out of sequence since each data unit is identified by a unique sequence number as described below. In the embodiment, if a hole (transmitted data units) is created (e.g., as the result of handoff between one to another base station), the missing data units are considered as though received in error. Mobile stations send NACK messages corresponding to the missing data units and these data units are retransmitted. [0069] In the exemplary embodiment, each base station maintains an independent data queue which contains the data to be transmitted to mobile stations. Each base station transmits data existing in its data queue in a sequential order, except for retransmissions of data units received in error and so on. In the exemplary embodiment, the transmitted data units are deleted from the queue.

#### V. Other Considerations for Forward Link Data Transmissions

[0070] An important consideration in the data communication system of the present invention is the C/I estimates for the purpose of selecting the data rate for future transmissions. In the exemplary embodiment, measurements are performed on the pilot signals during the time interval between pilot signals. In the exemplary embodiment, since only the pilot signals are transmitted during this pilot time interval, multipath and interference are minimal.

[0071] In other implementations of the present invention wherein the pilot signals are transmitted in an orthogonal code channel, similar to the effect of multipath and interference can degrade the C/I measurements. Similarly, when performing the C/I measurement on the data transmissions instead of pilot signals, multipath and interference can also degrade the C/I measurements. In both of these cases, when one base station is transmitting to one mobile station, the mobile station is able to accurately measure the C/I of the forward link because no other interfering signals are present. However, when a mobile station handoff and receives the pilot signals from multiple base stations, it is not able to discern whether or not base stations are transmitting data. In the worst case scenario, a mobile station receives a high C/I at a first time slot, when no base stations were transmitting data to any mobile station. At a second time slot, when two base stations are transmitting data at the same time slot. The C/I measurement at the first time slot gives a false indication of the forward link signal quality at the second time slot. The data communication system has changed. In fact, the actual C/I at the second time slot can be so low that reliable decoding at the requested data rate is not possible.

[0072] The converse extreme scenario exists when a C/I estimate is low due to maximal interference. However, the actual transmission occurs when only the selected base station is transmitting. In this case, the selected data rate is conservative and the transmission occurs at a rate lower than that which could be decoded, thus reducing the transmission efficiency.

[0073] In the implementation wherein the C/I measurement is performed on a continuous pilot signal, the prediction of the C/I at the second time slot based on the measurement of the C/I at the first time slot is made more accurate by three embodiments. In the first embodiment, data transmission from base stations is controlled so that base stations constantly toggle between the transmit and idle states at successive time slots. This can be achieved by queuing enough data (e.g. a predetermined number of information bits) before each transmission to mobile stations.

[0074] In the second embodiment, each base station transmits a forward activity bit (hereinafter referred to as FAC bit) which indicates whether a transmission will occur at the next half frame. The use of the FAC bit is described in detail below. Mobile stations perform the C/I measurement taking into account the received FAC bit from each base station.

[0075] In the third embodiment, which corresponds to the scheme wherein an indication of the link quality is sent from base stations to mobile stations and which uses a centralized scheduling scheme, the scheduling information indicating which base station transmitted data at each time slot is made available to each mobile station. Each mobile station receives the C/I measurements from mobile stations and adjusts the C/I measurements based on its knowledge of the presence or absence of data transmission from each base station in the data communication system. For example, mobile stations measure the C/I at the first time slot when no adjacent base stations are transmitting. The measured C/I is provided to the channel scheduler. The channel scheduler knows that no adjacent base stations transmitted data in the first time slot since none was scheduled by the channel scheduler. At the second time slot, the channel scheduler knows whether one or more adjacent base stations will transmit data. The channel scheduler 48 can adjust the C/I measured at the first time slot to take into account the data transmissions. Mobile stations will receive in the second time slot due to data transmissions by adjacent base stations. If the C/I is measured at the first time slot when adjacent base stations are not transmitting and these adjacent base stations are not transmitting at the second time slot, the mobile station adjusts the C/I measurement to take into account the additional information.

[0076] Another important consideration is to minimize redundant retransmissions. Redundant retransmissions result from allowing mobile stations to select data transmission from different base stations at different time slots. The best C/I measurement can toggle between two or more base stations over successive time slots if mobile stations measure approximately equal C/I for these base stations. This toggling can be due to deviations in the C/I measurements and/or changes in the channel condition. Data transmission by different base stations at different time slots can result in a loss in efficiency.

[0077] The toggling problem can be addressed by the use of hysteresis. The hysteresis can be implemented by a signal level scheme, a timing scheme, or a combination of the signal level and timing schemes. In the signal level scheme, the better C/I measurement of a different base station is not selected unless it exceeds the C/I measurement of the current transmitting base station by a hysteresis quantity. As an example, assume that the hysteresis is 1.0 dB and that the C/I measurement of the first base station is 10 dB at the first time slot. At the next time slot, if the C/I measurement of the second base station is 11.0 dB at the first time slot. At the next time slot, it is not selected unless its C/I measurement is at least 1.0 dB higher than that of the first base station. If the C/I measurement of the first base station is 11.5 dB at the next time slot, the second base station is selected unless its C/I measurement is at least 4.5 dB.

[0078] In the exemplary timing scheme, base stations transmit data packets to mobile stations at predetermined intervals of time. Mobile stations are allowed to select a different transmission rate at predetermined intervals of time. Mobile stations measure the C/I of the current transmission rate at a predetermined time slot and selects the data rate in response to the C/I measurement.

[0079] Yet another important consideration is the efficiency of the data transmission. Referring to FIG. 6, each data packet 600 and 430 contains data and overhead bits. In the exemplary embodiment, the number of overhead bits is fixed for all data rates. At the highest data rate, the percentage of overhead is small and the efficiency is high. At the lower data rates, the overhead bits can comprise a larger percentage of the data packet. The inefficiency at the lower data rates can be improved by transmitting variable length data packets. The variable length data packets can be partitioned and transmitted over multiple time slots. Preferably the variable length data packets are transmitted over multiple time slots to simplify the processing. The present invention is directed to the use of various packet sizes for various data rates to improve the overall transmission efficiency.

## VI. Forward Link Architecture

[0080] In the exemplary embodiment, base stations transmit at the maximum power available to a base station at the maximum data rate supported by the data communication system to a single mobile station. The maximum data rate that can be supported is dynamic and depends on the C/I of the forward link signal received by mobile stations. Preferably, base stations transmit to only one mobile station at any given time slot.

[0081] To facilitate data transmission, the forward link comprises four time multiplexed channels: a power control channel, a control channel, and traffic channel. The function and implementation of each channel are described below. In the exemplary embodiment, the traffic and power control channels each comprise a set of orthogonally spread Walsh channels. In the present invention, the traffic channel is used to transmit data, and the power control channel is used to transmit power control messages. In the present invention, the traffic channel is also used as the control channel in this specification.

[0082] In the exemplary embodiment, the bandwidth of the forward link is selected to be 1.2288 MHz. This selection allows the use of existing hardware components designed for a CDMA system which conform to the IS-54 standard. However, the data communication system of the present invention can be adopted for other bandwidths to improve capacity and/or to conform to system requirements. For example, a 5 MHz bandwidth can be utilized to increase the capacity. Furthermore, the bandwidths of the forward link and the reverse link can be different (e.g., 5 MHz bandwidth on the forward link and 1.2288 MHz bandwidth on the reverse link) to more efficiently use capacity with demand.

[0083] In the exemplary embodiment, the short PN codes are the same length PN codes which are specified by the IS-54 standard. At the 1.2288 MHz chip rate, the short PN sequences repeat every 26.67 msec =  $\frac{1}{1.2288 \times 10^6}$ . In the exemplary embodiment, the same short PN codes are used by all base stations in the data communication system. However, each base station is identified by a unique offset of the basic short PN sequences. In the exemplary embodiment, the offset is in increments of 64 chips. Other bandwidths can be utilized and are within the scope of the present invention.

## VII. Forward Link Traffic Channel

[0084] A block diagram of the exemplary forward link architecture of the present invention is shown in FIG. 7.

data is partitioned into data packets and provided to encoder 112. For each data packet, CRC and encoder generates frame check bits (e.g., the CRC parity bits) and inserts the code tail bits. The formatted packet 112 comprises the data, the frame check and code tail bits, and other overhead bits which are provided to interleaver 114. Interleaver 114, in the exemplary embodiment, encodes the packet in accordance with the encoding format disclosed in the aforementioned U.S. Patent Application Serial No. 08/743, 118. Other interleaving formats can also be used and are within the scope of the present invention. The encoded packet is provided to interleaver 116 which reorders the code symbols in the packet. The interleaved packet is provided to puncture element 118 which removes a fraction of the packet in the manner described below. The punctured packet is provided to multiplier 120 which scrambles the data with the scrambling sequence 122. The scrambled packet 118 and scrambling sequence 122 are described in detail below. The output of multiplier 120 is the scrambled packet. [0085] The scrambled packet is provided to variable rate multiplexer 124 which multiplexes the packet into K parallel inphase and quadrature channels, where K is dependent on the data rate. In the exemplary embodiment, the packet is first demultiplexed into the inphase (I) and quadrature (Q) streams. In the exemplary embodiment, the I stream comprises even indexed symbols and the Q stream comprises odd indexed symbol. Each stream is further provided to Walsh coder 132 which covers each channel with a Walsh function to provide orthogonal channels. The orthogonal channel data are provided to summer 134 which sums the data to maintain a constant energy per chip (and hence constant output power) for all data rates. The scaled data from summer 134 are provided to multiplexer 136 (MUX) which multiplexes the data with the preamble. The preamble is discussed below. The output from MUX 136 is provided to multiplexer 142 (MUX) which multiplexes the traffic data, the power control bits, and the pilot data. The output of MUX 142 is the I Walsh channels and the Q Walsh channels. [0086] A block diagram of the exemplary modulator used to modulate the data is illustrated in FIG. 2. The I Walsh channels and Q Walsh channels are provided to summer 212a and 212b, respectively, which sum the K Walsh channels to provide the signals  $I_{sum}$  and  $Q_{sum}$ , respectively. The  $I_{sum}$  and  $Q_{sum}$  signals are provided to complex multiplier 214. Complex multiplier 214 also receives the PN and P/Q signals from multiplexer 236a and 236b, respectively, and multiplies the two complex inputs in accordance with the following equation:

$$\begin{aligned} (I_{mult} + jQ_{mult}) &= (I_{sum} + jQ_{sum}) \cdot (PN\_I + jPN\_Q) \\ &= (I_{sum} \cdot PN\_I - Q_{sum} \cdot PN\_Q) + j(I_{sum} \cdot PN\_Q + Q_{sum} \cdot PN\_I) \end{aligned} \quad (2)$$

where  $I_{mult}$  and  $Q_{mult}$  are the outputs from complex multiplier 214 and  $PN\_I$  and  $PN\_Q$  are the complex representation of the I and Q signals. The I and Q signals are provided to filter 216a and 216b, respectively, which filters the signals. The filtered signals from filter 216a and 216b are provided to multiplier 218a and 218b, respectively, which multiplies the signals with the inphase and quadrature sinusoids,  $\cos(\omega_c t)$  and  $\sin(\omega_c t)$ , respectively. The I modulated and Q modulated signals are provided to summer 220 which sums the signals to provide the forward modulated waveform S. [0087] In the exemplary embodiment, the data packet is spread with the long PN code and the short PN code. The long PN code scrambles the packet such that only the packet which is destined is able to descramble the packet. In the exemplary embodiment, the pilot and power control bits and the control bits are spread with the short PN codes but not the long PN code to allow the receiver to receive the control bits. The long PN sequence is generated by long code generator 232 and provided to multiplexer 234 (MUX). The long PN mask determines the offset of the long PN sequence and is uniquely assigned to the mobile station. The output of MUX 234 is the long PN sequence during the data portion of the transmission and zero otherwise (during the pilot and power control portion). The gated long PN sequence and the short PN sequences are provided to multiplier 236a and 236b, respectively, which multiply the two sets of sequences to form the PN and P/Q signals, respectively. The PN and P/Q signals are provided to complex multiplier 214.

[0088] The block diagram of the exemplary traffic channel shown in FIGS. 3A and 3B is one of numerous architectures which support data encoding and modulation on the forward link. Other architectures, such as the forward link traffic channel in the CDMA system which is described in U.S. Patent Application Serial No. 08/743, 118, can also be utilized and are within the scope of the present invention.

[0089] In the exemplary embodiment which is not part of the invention, the data rates supported by the system are predetermined and each supported data rate is assigned a unique rate index. The mobile station reports the supported data rates based on the C/I measurement. Since the requested data rate needs to be sent to the base station to direct that base station to transmit data at the requested data rate, a trade off is made between the supported data rates and the number of bits needed to identify the requested data rate. In the exemplary embodiment, the number of bits needed to identify the requested data rate is 4.

the number of supported data rates is seven and index is used to identify the requested data rate. An exemplary definition of the supported data rates is illustrated in Table 1. Different definitions can be contemplated and are within the scope of the present embodiment.

[0090] In the exemplary embodiment which is not part of the invention, the minimum data rate is 38.4 Kbps and the maximum data rate is 2.4576 Mbps. The minimum data rate is selected based on the worst case C/I measurement of the system, the processing gain of the system, the design of the error correcting codes, and the system performance. In the exemplary embodiment, the supported data rates are chosen such that the difference between successive supported data rates is 3 dB. The 3 dB increment is a compromise among several factors including the accuracy of the C/I measurement that can be achieved by the mobile station (or base station or inefficiencies) which result from the quantization of the data rates based on the C/I measurement, and the number of bits (or bytes) required to transmit the requested data rate from the mobile station. More supported data rates requires more bits to identify the requested data rate but allows for more efficient use of the forward link because of the error between the calculated maximum data rate and the supported data rate. The present embodiment is not limited to the use of any number of supported data rates and other data rates than those listed in Table 1.

Table 1 - Traffic Channel Parameters

Parameter	Data Rates								Units
	38.4	76.8	153.6	307.2	614.4	1228.8	2457.6		Kbps
Data packet	1024	1024	1024	1024	1024	2048	2048		bits
Packet length	26.67	13.33	6.67	3.33	1.67	1.67	0.83		msec
Slot/packet	16	8	4	2	1	1	0.5		slots
Packet/transmission	1	1	1	1	1	1	2		packets
Slot/transmission	16	8	4	2	1	1	1		slots
Walsh symbol rate	153.6	307.2	614.4	1228.8	2457.6	2457.6	4915.2		Ksps
Walsh channel/ QPSK phase 1	2	4	8	16	16	16	channels		
Modulator rate	76.8	76.8	76.8	76.8	76.8	76.8	76.8		Ksps
PN chips/data bit	32	16	8	4	2	1	0.5		chips/bit
PN chip rate	1228.8	1228.8	1228.8	1228.8	1228.8	1228.8	1228.8		Kcps
Modulation format	QPSK	QPSK	QPSK	QPSK	QPSK	QPSK	QAM <sup>1</sup>		
Rate index	0	1	2	3	4	5	6		
Note: (1) QAM modulation									

[0091] A diagram of the exemplary forward link frame structure of the present invention is illustrated in Figure 1. The traffic channel transmission is partitioned into frames which, in the exemplary embodiment, are defined by the short PN sequences or 26.67 msec. Each frame can carry control channel information addressed to the mobile station (control channel frame), traffic data addressed to a particular mobile station, or be empty (idle frame). The content of each frame is determined by the scheduling performed by the transmitter. In the exemplary embodiment, each frame comprises 16 time slots, with each time slot having a duration of 1.667 msec. A time slot of 1.667 msec is adequate to enable the mobile station to perform the C/I measurement of the forward link signal. A time slot of 1.667 msec also represents a sufficient amount of time for efficient packetization. In the exemplary embodiment, each time slot is further partitioned into four quarter slots.

[0092] In the present invention, each data packet is transmitted over one or more time slots as shown in Figure 2. In the exemplary embodiment, each forward link data packet comprises 1024 or 2048 bits. Thus, the number of time slots required to transmit each data packet is dependent on the data rate and ranges from 16 time slots for the 38.4 Kbps rate to 1 time slot for the 2.4576 Mbps rate and higher.

[0093] An exemplary diagram of the forward link slot structure of the present invention is shown in Figure 3. In the exemplary embodiment, each slot comprises three of the four time multiplexed channels, the traffic channel, the pilot channel, and the power control channel. In the exemplary embodiment, the pilot channels are transmitted in two pilot and power control bursts which are located at the same position in each slot. The pilot and power control bursts are described in detail below.

[0094] In the exemplary embodiment, the interleaved packet from a single user is punctured to accommodate the pilot and power control bursts. In the exemplary embodiment, each interleaved packet comprises 4096 code symbols and the first 512 code symbols are punctured, as shown in FIG. 4D. The remaining code symbols are interleaved to align to the traffic channel transmission intervals.

[0095] The punctured code symbols are scrambled to randomize the data prior to applying the orthogonal spreading code. The randomization limits the average peak envelope on the modulated wave for the scrambling sequence can be generated with a linear feedback shift register, in a manner known in the art. In the exemplary embodiment, the LFSR 122 is loaded with the LC state at the start of each slot. In the exemplary embodiment, the LFSR 122 is synchronous with the clock of the traffic channel.

[0096] In the exemplary embodiment, the forward Walsh channels (for the traffic channel and power control) are orthogonally spread with Walsh covers at the fixed chip rate of 1.2288 Mcps. The number of parallel Walsh channels K per inphase and quadrature signal is a function of the data rate, as shown in Table 2. In the exemplary embodiment, for lower data rates, the inphase and quadrature Walsh covers are chosen to be orthogonal to each other to avoid cross-talk to the demodulator phase estimate errors. For example, for 16 Walsh channels, an exemplary inphase signal is  $\cos(2\pi f_c t)$  and a quadrature signal is  $\sin(2\pi f_c t)$ .

[0097] In the exemplary embodiment, QPSK modulation is used for data rates of 1.2288 Mbps and lower. For higher data rates, 16-QAM is used and the scrambled data is demultiplexed into 32 parallel streams which are each modulated with a Walsh cover. In the exemplary embodiment, the QAM modulation inputs of (0, 1, 3, 2) map to modulation values of (+3, +1, -1, -3), respectively. The modulation schemes, such as any phase shift keying PSK, can be contemplated and are within the scope of the present invention.

[0098] The inphase and quadrature Walsh channels are scaled prior to modulation to maintain a constant average power which is independent of the data rate. The gain settings are normalized to a unity reference power level. The normalized channel gains G as a function of the number of Walsh channels (or K) are shown in Table 2. Also listed in Table 2 is the average power per Walsh channel (inphase or quadrature) for each data rate. The total normalized power is equal to unity. Note that the normalized power per Walsh chip is 1 for QPSK and 0.25 for 16-QAM.

Table 2 -Traffic Channel Orthogonal Channel Gains

Data Rate (Kbps)	Puncture Duration			
	Number of Walsh Channels K	Modulation	Walsh Channel Gain G	Average Power per Channel P
38.4	1	QPSK	1/2	1/2
76.8	2	QPSK	1/2	1/4
153.6	4	QPSK	1/22	1/8
307.2	8	QPSK	1/4	1/16
614.4	16	QPSK	1/42	1/32
1228.8	16	QPSK	1/42	1/32
2457.6	16	16-QAM	1/4 10	1/32

[0099] In the present invention, a preamble is punctured into each traffic frame to assist mobile station synchronization with the first slot of each variable rate transmission. In the exemplary embodiment, the preamble is a zero sequence which, for a traffic frame, is spread with the long PN code but, for a control frame, is not spread with the long PN code. In the exemplary embodiment, the preamble is unmodulated BPSK which is spread with Walsh cover. The use of a single orthogonal channel minimizes the average peak envelope. Also, the use of a zero Walsh cover minimizes false pilot detection since, for traffic frames, the pilot is spread with Walsh cover and both the pilot and the preamble are not spread with the long PN code.

[0100] The preamble is multiplexed into the traffic channel stream at the start of the packet for each data rate. The length of the preamble is such that the preamble overhead is approximately 3.1 percent for all data rates while minimizing the probability of false detection. A summary of the preamble as a function of the data rate is shown in Table 3. Note that the preamble comprises 3.1 percent or less of a data packet.

Table 3 - Preamble Parameters

Data Rate (Kbps)	Preamble Puncture Duration		
	Walsh Symbols	PN chips	Overhead
38.4	32	512	1.6%
76.8	16	256	1.6%
153.6	8	128	1.6%
307.2	4	64	1.6%
614.4	3	48	2.3%
1228.8	4	64	3.1%
2457.6	2	32	3.1%

## VIII. Forward Link Traffic Frame Format

[0101] In the exemplary embodiment, each data packet is formatted by the additions of frame check bits, and other control fields. In this specification, an octet is defined as 8 information bits and comprises 8 information bits.

[0102] In the exemplary embodiment, the forward link supports two data packet formats which are illustrated in FIG. 4E and 4F. Packet format 410 comprises five fields and packet format 430 comprises nine fields. Packet format 410 is used when the data packet to be transmitted to mobile station 6 contains enough data to complete 416 octets in DATA field. If the amount of data to be transmitted is less than the available octets in packet format 410 is used. The unused octets are padded with all zeros and designated as PADDING field.

[0103] In the exemplary embodiment, frame check sequence (FCS) and FCS field contain the CRC parity bits which are generated by CRC generator (see FIG. 3A) in accordance with a predetermined generator polynomial.

In the exemplary embodiment, the CRC polynomial is  $x^{16} + x^{12} + x^5 + 1$ , although other polynomials can be used and are within the scope of the present invention. In the exemplary embodiment, the CRC bits are calculated over FMT, SEQ, LEN, DATA, and PADDING fields. This provides error detection over all bits, except the control bits 420 and 448, transmitted over the traffic channel on the forward link. In the alternative embodiment, the CRC bits are calculated only over the DATA field. In the exemplary embodiment, 16 CRC parity bits, although other CRC generators providing different number of parity bits can be used and are within the scope of the present invention. Although FCS and FCS fields of the present invention has been described in the context of CRC parity bits, other frame check sequences can be used and are within the scope of the present invention. For example, a check sum can be calculated for the packet and provided in the FCS field.

[0104] In the exemplary embodiment, frame format 410 and 430 contain one control bit which indicates whether the data frame contains only data octets (packet format 410) and padding octets and zero or more messages (packet format 430). In the exemplary embodiment, a low value for FMT corresponds to packet format 410. Alternatively, a high value for FMT corresponds to packet format 430.

[0105] Sequence number (SEQ) fields 416 and 442 identify the first data unit 418 and 444 respectively. The sequence number allows data to be transmitted out of sequence to the mobile station for retransmission of packets which have been received in error. The assignment of the sequence number at the data unit 418 allows the need for frame fragmentation protocol for retransmission. The sequence number 416 also allows mobile station 6 to detect duplicate data units. Upon receipt of the FMT, SEQ, and LEN fields, mobile station 6 determines which data units have been received at each time slot without the use of special signaling messages.

[0106] The number of bits assigned to represent the sequence number is dependent on the maximum number of data units which can be transmitted in one time slot and the worst case data retransmission delays. In the exemplary embodiment, each data unit is identified by a 24 number. At the 2.4576 Mbps data rate, the maximum number of data units which can be transmitted at each slot is approximately 256. Eight bits are required to represent 256 data units. Furthermore, it can be calculated that the worst case data retransmission delays are approximately 100 ms. The retransmission delays include the time necessary for a NACK message by the mobile station of the data, and the number of retransmission attempts caused by the worst case burst error runs. Therefore, mobile station 6 can properly identify the data units being received without ambiguity. The number of bits for SEQ fields 416 and 442 can be increased or decreased, depending on the size of the DATA field and transmission delays. The use of different number of bits for SEQ fields is within the scope of the present invention.



[0107] When base station has less data to transmit to mobile station, space available in DATA field packet format 10 is used. Packet format 10 allows base station to transmit any number of data units, up to maximum number of available data units, to mobile station. In the exemplary embodiment, a high value for FMT field 434 indicates that base station transmitting packet 10 for within packet format 10, LEN field 440 contains the value of the number of data units being transmitted in that packet. In the exemplary embodiment, 8 bits in length since DATA field range from 0 to 255 octets.

[0108] DATA field 438 and 444 contain the data to be transmitted to mobile station. In the exemplary embodiment, for packet format 10, each data packet comprises 1024 bits of which 992 are data bits. However, variable packets can be used to increase the number of information bits and are within the scope of the present invention. In packet format 10, the size of DATA field is determined by LEN field 440.

[0109] In the exemplary embodiment, packet format 10 can be used to transmit zero or more signaling messages. Signaling length (SIG LEN) field 436 contains the length of the subsequent signaling messages, in octets. In the exemplary embodiment, SIG LEN field 436 is 8 bits in length. SIGNALING field 438 contains the signaling messages. In the exemplary embodiment, each signaling message comprises a message identification (MESSAGE ID) field 442, length (LEN) field, and a message payload, as described below.

[0110] PADDING field 446 contains padding octets which, in the exemplary embodiment, are set to 0. PADDING field 446 is used because base station may have fewer data octets to transmit to mobile station. The number of octets available in DATA field and this occurs, PADDING field 446 contains enough padding octets to fill the unused data field. PADDING field 446 is variable length and depends on the length of DATA field 440.

[0111] The last field of packet format 10 is TAIL field 442 and 448, respectively. TAIL field 442 and 448 contain the zero (0x0) code tail bits which are used to force the encoder into a known state at the end of each data packet. The code tail bits allow the decoder to correctly partition the packet such that only bits used in the encoding process. The code tail bits also allow the decoder to determine the packet boundaries during the decoding process. The number of TAIL field 442 and 448 depends on the design of encoder. In the exemplary embodiment, TAIL field 442 and 448 are long enough to force the encoder to a known state.

[0112] The two packet formats described above are exemplary formats which can be used to facilitate transmission of data and signaling messages. Various other packet formats can be created to meet the needs of a communication system. Also, a communication system can be designed to accommodate more than the two packet formats described above.

#### IX. Forward Link Control Channel Frame

[0113] In the present invention, the traffic channel is also used to transmit messages from base station to mobile station. The types of messages transmitted include: (1) handoff direction messages, (2) paging messages to page a specific mobile station, (3) there is data in the queue for that mobile station, (4) there are data packets for a specific mobile station, (4) ACK or NACK messages for the reverse link data transmissions (to be described herein). Other types of messages can also be transmitted on the control channel and are within the scope of the present invention. Upon completion of the call set up stage, the mobile station monitors the control channel for paging messages and begins transmission of the reverse link pilot signal.

[0114] In the exemplary embodiment, the control channel is time multiplexed with the traffic data channel as shown in FIG. 4A. Mobile station identifies the control message by detecting a preamble which has been transmitted with a predetermined PN code. In the exemplary embodiment, the control messages are transmitted at a rate determined by mobile station acquisition. In the preferred embodiment, the data rate of the control channel is 76.8 Kbps.

[0115] The control channel transmits messages in control channel capsules. The diagram of an exemplary control channel capsule is shown in FIG. 4G. In the exemplary embodiment, each capsule 462 comprises a preamble field 464, a payload field 466, and a CRC parity field 470. The control payload comprises one or more messages and, if necessary, a message length field 472. Each message comprises message identifier field 468, message length field 472, optional address field 468 (e.g., if the message is directed to a specific mobile station). In the exemplary embodiment, the messages are aligned to octet boundaries. The exemplary control channel capsule 462 in FIG. 4G comprises two broadcast messages intended for all mobile stations and one message directed at a specific mobile station. MSG ID field 474 determines whether or not the message requires an address field (e.g., whether the message is a broadcast or a specific message).

#### X. Forward Link Pilot Channel

[0116] In the present invention, a forward link pilot channel provides a pilot signal which is used for channel estimation.

for initial acquisition, phase recovery, timing recovery, and ratio combining. These uses are similar to those of communication systems which conform to the standard. In the exemplary embodiment, the pilot signal is also used by mobile stations to perform the C/I measurement.

[0117] The exemplary block diagram of the forward link pilot channel of the present invention is shown in FIG. 3B. The pilot data comprises a sequence of all zeros (or all ones) which is multiplied by a Walsh code. The Walsh code is a sequence of all zeros, the output of the multiplier is the pilot data. The pilot data is time multiplexed with the I Walsh channel which is spread by a short PN code within complex multipliers (FIG. 3B). In the exemplary embodiment, the pilot data is not time multiplexed with the long PN code, which is gated off during the pilot burst by a MUX. The pilot signal is thus an unmodulated BPSK signal.

[0118] A diagram illustrating the pilot signal is shown in FIG. 4B. In the exemplary embodiment, each pilot burst 306a and 306b which occur at the end of the first and third quarters of the time slot. In the exemplary embodiment, each pilot burst is 64 chips in duration ( $T_p=64$  chips). In the absence of traffic data or power control data, base station only transmits the pilot and power control bursts, resulting in a discontinuous waveform at the periodic rate of 1200 Hz. The pilot modulation parameters are tabulated in Table 4.

# XI. Reverse Link Power Control

[0119] In the present invention, the forward link power control channel is used to send the power control commands which is used to control the transmit power of the reverse link transmission from the mobile station to the base station. Each transmitting mobile station is a source of interference to all other mobile stations. To minimize interference on the reverse link and maximize capacity, the transmit power of each mobile station is controlled by two power control loops. In the exemplary embodiment, the power control loops are similar to those disclosed in detail in U.S. Patent No. 5,056,109, entitled "METHOD AND APPARATUS FOR CONTROLLING TRANSMISSION POWER IN A CDMA CELLULAR MOBILE TELEPHONE SYSTEM", assigned to the assignee of the present invention. Other power control mechanism can also be contemplated and are within the scope of the present invention.

[0120] The first power control loop adjusts the transmit power of each mobile station such that the reverse link signal quality is maintained at a set level. The signal quality is measured in terms of the energy per chip to noise power spectral density ratio  $E_b/N_0$  of the reverse link signal received at the base station. This ratio is referred to as the set point. The second power control loop adjusts the set point such that the desired level of performance, as measured by the frame error rate (FER), is maintained. Power control is critical on the reverse link because the transmit power of each mobile station is an interference to other mobile stations in the communication system. Minimizing the reverse link transmit power reduces the interference and increases the reverse link capacity.

[0121] Within the first power control loop, the reverse link signal is measured at the base station. The base station then compares the measured  $E_b/N_0$  with the set point. If the measured  $E_b/N_0$  is greater than the set point, base station 4 transmits a power control message to mobile station 6 to decrease the transmit power. Alternatively, if the measured  $E_b/N_0$  is below the set point, base station 4 transmits a power control message to mobile station 6 to increase the transmit power. In the exemplary embodiment, the power control message is implemented with one power control bit. In an exemplary embodiment, a high value for the power control bit commands mobile station 6 to increase its transmit power and a low value commands mobile station 6 to decrease its transmit power.

[0122] In the present invention, the power control bits for all mobile stations are transmitted on the power control channel. In the exemplary embodiment, the power control channel consists of 32 orthogonal channels which are spread with Walsh codes. Each Walsh channel transmits one reverse link power control (RPC) bit or one FAC bit at periodic intervals. Each channel is assigned an RPC index which defines the Walsh code and QPSK modulation phase (e.g. in phase or quadrature) for transmitting the RPC bit stream destined for that mobile station. In the exemplary embodiment, the RPC index of 0 is reserved for the power control channel.

[0123] The exemplary block diagram of the power control channel is shown in FIG. 3A. The RPC bits are time multiplexed with a pilot signal which repeats each RPC bit a predetermined number of times. The repeated RPC bits are then multiplied by a Walsh code which covers the bits with the Walsh codes corresponding to the RPC indices. The output of the multiplier is the power control signal. The gains of the RPC Walsh channels are normalized so that the total transmit power is equal to the total available transmit power. The gains of the Walsh channels can be varied for efficient utilization of the total base station transmit power while maintaining reliable RPC transmission. In the exemplary embodiment, the Walsh channel gains of inactive mobile stations are set to zero. Automatic power control of the RPC Walsh channels is possible using estimates of the forward link quality from the corresponding DRC channel from mobile stations. The estimated RPC bits from gain elements are provided to MUX 162.

[0124] In the exemplary embodiment, the RPC indices of 0 through 15 are assigned through Walsh covers  $W_0$  through  $W_{15}$  respectively, and are transmitted around the first pilot burst within a slot (FIG. 4C). The RPC indices of 16 through 31 are assigned to Walsh covers  $W_{16}$  through  $W_{31}$  respectively, and are transmitted around the second pilot burst within a slot (FIG. 4C). In the exemplary embodiment, the RPC bits are BPSK modulated with the even Walsh covers (e.g.,  $W_0, W_2, W_4$ , etc.) modulated on the inphase signal and the odd Walsh covers (e.g.,  $W_1, W_3, W_5$ , etc.) modulated on the quadrature signal. To reduce the peak-to-average power ratio, it is preferable to balance the inphase and quadrature power. Furthermore, to minimize the carrier phase estimate error, it is preferable to assign orthogonal covers to the inphase and quadrature signals.

[0125] In the exemplary embodiment, up to 31 RPC bits can be transmitted on 31 RPC Walsh channels within a slot. In the exemplary embodiment, 15 RPC bits are transmitted on the first half slot and 16 RPC bits on the second half slot. The RPC bits are combined by a summer (FIG. 3B) and the composite waveform of the power control channel is as shown in FIG. 4C.

[0126] A timing diagram of the power control channel is illustrated in FIG. 4B. In the exemplary embodiment, the bit rate is 600 bps, or one RPC bit per time slot. Each RPC bit is time multiplexed and transmitted (e.g., RPC bursts 304a and 304b), as shown in FIGS. 4B and 4C. In the exemplary embodiment, each RPC burst is 64 PN chips (or 2 Walsh symbols) in width ( $T_{pc}=32$  chips) and the total width of each RPC bit is 64 PN chips (or 2 Walsh symbols). Other RPC bit rates can be obtained by changing the number of symbol repetition. For example, a rate of 1200 bps (to support up to 63 mobile stations) or to increase the power control rate) can be obtained by transmitting the first set of 31 RPC bits on RPC burst 304a and the second set of 32 RPC bits on RPC burst 304b. In this case, all Walsh covers are used in the inphase and quadrature modulation parameters for the RPC bits are summarized in Table 4.

Table 4 - Pilot and Power Control Modulation Parameters

Parameter	RPC	FAC	Pilot	Units
Rate	600	75	1200	Hz
Modulation format	QPSK	QPSK	BPSK	
Duration of control bit	64	1024	64	PN chips
Repeat	4	64	4	symbols

[0127] The power control channel has a bursty nature since the number of mobile stations with each base station can be less than the number of available RPC Walsh channels. In this situation, some channels are set to zero by proper adjustment of the gain of gain element.

[0128] In the exemplary embodiment, the RPC bits are transmitted to mobile stations in an interleaved manner to minimize processing delays. Furthermore, the erroneous reception of the power control bit is not a problem in the data communication system of the present invention since the error can be corrected in the next time slot.

[0129] In the present invention, mobile stations soft handoff with multiple base stations. The method and apparatus for the reverse link power control for mobile stations is disclosed in the aforementioned U.S. Patent No. 5,056,109. Mobile stations handoff monitors the RPC Walsh channel for each base station in the active set and combines the RPC bits in accordance with the method disclosed in the U.S. Patent No. 5,056,109. In the first embodiment, the mobile station performs a logic OR of the down power commands. Mobile stations increase the transmit power if any one of the received RPC bits commands the mobile station to increase the transmit power. In the second embodiment, mobile stations handoff can combine the soft decisions of the received RPC bits before making a hard decision. Other embodiments for processing the received RPC bits can be used and are within the scope of the present invention.

[0130] In the present invention, the FAC bit indicates to mobile stations the traffic channel of the associated pilot channel will be transmitting on the next half frame. The use of the FAC bit improves the mobile stations and hence the data rate request, by broadcasting the knowledge of the interference level. In the exemplary embodiment, the FAC bit only changes at half frame boundaries and is repeated for eight time slots, resulting in a bit rate of 75 bps. The parameters for the FAC bit is listed in Table 4.

[0131] Using the FAC bit, mobile stations compute the C/I measurement as follows:

$$\left(\frac{C}{I}\right)_i = \frac{C_i}{I - \sum_{j \neq i} (1 - \alpha_j) C_j} \quad (3)$$

where  $(C/I)_i$  is the C/I measurement of forward link signal,  $C_i$  is the received power of forward link signal,  $I$  is the total interference after cancellation,  $\alpha_j$  is the FAC bit of forward link signal and can be 0 or 1 depending on the FAC bit.

### XII. Reverse Link Data Transmission

[0132] In the present invention, the reverse link supports variable rate data transmission. The flexibility and allows mobile stations to transmit at one of several data rates, depending on the amount of data to be transmitted to base station. In the exemplary embodiment, mobile stations transmit data at the lowest data rate at any time. In the exemplary embodiment, data transmission at higher data rates requires a grant. This implementation minimizes the reverse link transmission delay while providing efficient utilization of the reverse link resource.

[0133] An exemplary illustration of the flow diagram of the reverse link data transmission of the present invention is shown in FIG. 8. Initially, at slot 6, mobile station transmits an access probe, as described in the aforementioned Patent No. 5,289,527, to establish the lowest rate data channel on the reverse link at block 802. Base station demodulates the access probe and receives the access message. Base station grants the request for the data channel and, at slot n+2, transmits the grant and the assigned RPC index on the reverse link at block 806. At slot n+2, mobile station receives the grant and is power controlled by base station. Beginning at slot n+3, mobile station starts transmitting the pilot signal and has immediate access to the data channel on the reverse link.

[0134] If mobile station has traffic data and requires a high rate data channel, mobile station requests a high rate data channel at block 810. At slot n+3, base station receives the high speed data request. At block n+5, base station transmits the grant on the control channel. At block n+5, mobile station receives the grant and begins high speed data transmission on the reverse link starting at slot n+6, at block 818.

### XIII. Reverse Link Architecture

[0135] In the data communication system of the present invention, the reverse link transmission differs from the forward link transmission in several ways. On the forward link, data transmission typically comes from one mobile station. However, on the reverse link, each base station currently receives data transmissions from multiple mobile stations. In the exemplary embodiment, each mobile station transmits at one of several data rates depending on the amount of data to be transmitted to base station. This system design reflects the asymmetric characteristic of data communication.

[0136] In the exemplary embodiment, the time base unit on the reverse link is identical to the time base unit on the forward link. In the exemplary embodiment, the forward link and reverse link data transmissions occur in time slots which are 1.667 msec in duration. However, since data transmission on the reverse link typically occurs at a lower rate, a longer time base unit can be used to improve efficiency.

[0137] In the exemplary embodiment, the reverse link supports two channels: the pilot/DRC channel and the data channel. The function and implementation of each of these channels are described below. The pilot/DRC channel is used to transmit the pilot signal and the DRC messages and the data channel is used to transmit traffic data.

[0138] A diagram of the exemplary reverse link frame structure of the present invention is illustrated in FIG. 9. In the exemplary embodiment, the reverse link frame structure is similar to the forward link frame structure. However, on the reverse link, the pilot/DRC data and traffic data are transmitted concurrently on two orthogonal quadrature channels.

[0139] In the exemplary embodiment, mobile station transmits a DRC message on the pilot/DRC channel at each time slot whenever mobile station is receiving high speed data transmission. Alternatively, when mobile station is not receiving high speed data transmission, the entire slot on the pilot/DRC channel comprises the pilot signal. The pilot signal is used by the receiving base station for a number of functions: as an aid to initial acquisition, as a reference for the pilot/DRC and the data channels, and as the source for the closed loop reverse link power control.

[0140] In the exemplary embodiment, the bandwidth of the reverse link is selected to be 1.2288 MHz. This bandwidth selection allows the use of existing hardware designed for a CDMA system which conforms to the IS-95 standard. However, other bandwidths can be utilized to increase capacity and/or to conform to system requirements.

emplary embodiment, the same long PN code and short PN codes as those specified by standard are used to spread the reverse link signal. In the exemplary embodiment, the reverse link channels use QPSK modulation. Alternatively, QPSK modulation can be used to minimize the amplitude variation of the modulated signal which can result in improved performance. The use of different system bandwidths and modulation schemes can be contemplated and are within the scope of the present invention. [0141] In the exemplary embodiment, the transmit power of the reverse link transmissions on the pilot and the data channel are controlled such that the reverse link signal, as measured at base station, is maintained at a predetermined EIRP point as discussed in the aforementioned U.S. Patent No. 5,506,109. This power control is maintained by base station communication with the mobile station and the commands are transmitted as the RPC bits as discussed above.

#### XIV. Reverse Link Data Channel

[0142] A block diagram of the exemplary reverse link architecture of the present invention is shown in FIG. 6. The data is partitioned into data packets and provided to encoder 610. For each data packet, encoder 610 generates the CRC parity bits, inserts the code tail bits, and encodes the data. In the exemplary embodiment, encoder 610 encodes the packet in accordance with the encoding format disclosed in the aforementioned U.S. Patent Application No. 08/743,688. Other encoding formats can also be used and are within the scope of the present invention. The encoded packet from encoder 610 is provided to block interleaver 612 which reorders the code symbols in the packet. The interleaved packet is provided to gain element 614 which multiplies the data with the Walsh cover and provides the coded data to gain element 618. Gain element 618 scales the data to maintain a constant power level regardless of the data rate. The scaled data from gain element 618 is provided to multipliers 650a and 650b which spread the data with the PN<sub>Q</sub> and PN<sub>I</sub> sequences, respectively. The spread data from multipliers 650a and 650b is provided to filters 652a and 652b, respectively, which filter the data. The filtered signals from filters 652a and 652b are provided to summer 654a and the filtered signals from filters 652c and 652d are provided to summer 654b. Summer 654a sums the signals from the data channel with the signals from the pilot/DRC channel. The output of summer 654a provides IOUT and QOUT, respectively, which are modulated with the inphase and quadrature sinusoids SIN(w<sub>c</sub>t), respectively (as in the forward link), and summed (not shown in FIG. 6). In the exemplary embodiment, traffic data is transmitted on both the inphase and quadrature phase of the sinusoid.

[0143] In the exemplary embodiment, the data is spread with the long PN code and the short PN codes. The long PN code scrambles the data such that the receiving base station can identify the transmitting mobile station. The short PN code spreads the signal over the system bandwidth. The long PN sequence is generated by long code generator 642 and provided to multipliers 646a and 646b. The short PN sequences are generated by short code generator 644 and also provided to multipliers 646a and 646b, respectively, which multiply the two sets of sequences to form the PN<sub>Q</sub> and PN<sub>I</sub> signals, respectively. Timing generator 640 provides the timing reference.

[0144] The exemplary block diagram of the data channel architecture as shown in FIG. 6 is one of many architectures which support data encoding and modulation on the reverse link. For high rate data transmission, the architecture is similar to that of the forward link utilizing multiple orthogonal channels can also be used. Other architectures for the reverse link traffic channel in the CDMA system are also contemplated and are within the scope of the present invention.

[0145] In the exemplary embodiment, the reverse link data channel supports four data rates which are listed in Table 5. Additional data rates and/or different data rates can be supported and are within the scope of the present invention. In the exemplary embodiment, the packet size for the reverse link is dependent on the data rate as listed in Table 5. As described in the aforementioned U.S. Patent Application Serial No. 08/743,688, improved performance can be obtained for larger packet sizes. Thus, different packet sizes than those listed in Table 5 to improve performance and are within the scope of the present invention. In addition, the packet size is a parameter which is independent of the data rate.

Table 5 - Pilot and Power Control Modulation Parameters

Parameter	Data rates				Units
	9.6	19.2	38.4	76.8	Kbps
Frame duration	26.66	26.66	13.33	13.33	msec
Data packet length	245	491	491	1003	bits
CRC length	16	16	16	16	bits
Code tail bits		5	5	5	bits

(continued)

Parameter	Data rates				Units
Total packet	256	512	512	1024	bits
Encoded packet length	1024	2048	2048	4096	symbols
Walsh symbol length	32	16	8	4	chips
Request required	no	yes	yes	yes	

[0146] As shown in Table 5, the reverse link supports a plurality of data rates. In the exemplary embodiment, the lowest data rate of 9.6K bps is allocated to each mobile station with base station. In the exemplary embodiment, mobile stations transmit data on the lowest rate data channel at any time slot with request permission from base station. In the exemplary embodiment, data transmission at the higher data rate is granted by the selected base station on a set of system parameters such as the system loading, fairness, and total throughput. An exemplary scheduling mechanism for high speed data transmission is described in the aforementioned U.S. Patent Application Serial No. 08/798,951.

#### XV. Reverse Link Pilot/DRC Channel

[0147] The exemplary block diagram of the pilot/DRC channel is shown in FIG. 6. The DRC message is encoded by a DRC encoder 626 which encodes the message in accordance with a predetermined coding format. Coding of the DRC message is important since the error probability of the DRC message needs to be sufficiently low for the forward link data rate determination impacts the system throughput performance. In the exemplary embodiment, encoder 626 is a rate (8,4) CRC block encoder which encodes the DRC message into a 128 bit code word. The encoded DRC message is provided to a multiplier 628 which covers the message with the Walsh code which uniquely identifies the destination base station to which the DRC message is directed. The Walsh code is provided by a Walsh code generator 624. The covered DRC message is provided to a multiplexer 630 which multiplexes the message with the pilot data. The DRC message and the pilot data are provided to a DSSS modulator 650 which spreads the data with the PN and PM signals, respectively. Thus, the pilot and DRC message are transmitted on both the in-phase and quadrature phase of the sinusoid.

[0148] In the exemplary embodiment, the DRC message is transmitted to the selected base station by covering the DRC message with the Walsh code which identifies the selected base station. In the exemplary embodiment, the Walsh code is 128 chips in length. The chip Walsh codes are known in the art. One unique Walsh code is assigned to each base station in communication with mobile stations. Each base station 4 decodes the signal on the DRC channel with its assigned Walsh code. The selected base station 4 decodes the DRC message and transmits data to the requesting mobile station and link in response thereto. Other base stations are able to determine that the requested data rate is not directed to them because the other base stations 4 are assigned different Walsh codes.

[0149] In the exemplary embodiment, the reverse link short PN codes for all the base stations in the communication system is the same and there is no offset in the short PN sequences to distinguish the different base stations. The communication system of the present invention supports soft handoff on the reverse link. Using the same PN codes with no offset allows multiple base stations the same reverse link transmission from mobile station 6 during a soft handoff. The short PN codes provide spectral spreading but do not allow for identification of the base station.

[0150] In the exemplary embodiment which is not part of the invention, the DRC message carries the requested data rate by mobile station. In the alternative embodiment, the DRC message carries an indication of the forward link C/I (e.g., the C/I information as measured by mobile station) and the mobile station can simultaneously receive the forward link pilot signals from one or more base stations and perform the C/I measurement on each received pilot signal. The mobile station then selects the best base station on a set of parameters which can comprise present and predicted C/I measurements. The rate control information is formatted into the DRC message which can be communicated to the selected base station in one of several embodiments.

[0151] In the first embodiment which is not part of the invention, the reverse link DRC message is based on the requested data rate. The requested data rate is the highest supported data rate which yields satisfactory performance at the C/I measured by mobile station. From the C/I measurement, mobile station calculates the maximum data rate which yields satisfactory performance. The maximum data rate is then quantized to one of the supported data rates and designated as the requested data rate. The data rate index corresponding to the requested data rate is then communicated to the selected base station. In the exemplary set of supported data rates and the corresponding data rate index shown in Table 1.

[0152] In the second embodiment, wherein mobile station transmits an indication of the forward link quality, selected base station transmits a C/I index which represents the quantized value of the measurement. The C/I measurement can be mapped to a table and associated with a C/I index. Using more than one C/I index allows a finer quantization of the C/I measurement. Also, the mapping can be linear or non-linear. In linear mapping, each increment in the C/I index represents a corresponding increase in the C/I measurement. For example, each step in the C/I index can represent a 2.0 dB increase in the C/I measurement. For a non-linear mapping, each increment in the C/I index can represent a different increase in the C/I measurement. As an example, a non-linear mapping can be used to quantize the C/I measurement to match the cumulative distribution function of the C/I distribution as shown in FIG. 10.

[0153] Other embodiments to convey the rate control information from mobile station to base station are contemplated and are within the scope of the present invention. Furthermore, the use of different methods to represent the rate control information is also within the scope of the present invention. Through the present invention, the present invention is described in the context of the first embodiment which is not part of the present invention. The use of a DRC message to convey the requested data rate, for simplicity.

[0154] In the exemplary embodiment, the C/I measurement can be performed on the forward link pilot signal in a manner similar to that used in the CDMA system. A method and apparatus for performing the C/I measurement is disclosed in U.S. Patent Application Serial No. 08/722,763, entitled "METHOD AND APPARATUS FOR MEASURING FORWARD LINK QUALITY IN A SPREAD SPECTRUM COMMUNICATION SYSTEM", filed September 27, 1996, assigned to the assignee of the present invention. In summary, the C/I measurement on the pilot signal can be obtained by correlating the received signal with the short PN codes. The C/I measurement on the pilot signal can contain an indication of whether the channel condition changed between the time of the C/I measurement and the time of actual data transmission. In the present embodiment, the use of the FAC bit allows mobile station to consider the forward link condition when determining the requested data rate.

[0155] In the alternative embodiment, the C/I measurement can be performed on the forward link traffic channel signal. The traffic channel signal is first despread with the long PN code and the short PN codes and decoded with the long PN code. The C/I measurement on the signals on the data channels can be more accurate because a large portion of the transmitted power is allocated for data transmission. Other methods to measure the C/I of the forward link signal by mobile station are also contemplated and are within the scope of the present invention.

[0156] In the exemplary embodiment which is not part of the invention, the DRC message is transmitted in a specific time slot (see FIG. 7A). For an exemplary time slot of 1.667 msec, the DRC message comprises 1024 chips or 0.83 msec of the time slot. The remaining 1024 chips of time are used by base station to decode the message. Transmission of the DRC message in the earlier portion of the time slot allows base station to decode the DRC message within the same time slot and possibly transmit data at the requested data rate in the successive time slot. The short processing delay allows the communication system of the present invention to adapt to changes in the operating environment.

[0157] In the alternative embodiment, the requested data rate is conveyed to base station by absolute reference and a relative reference. In this embodiment, the absolute reference comprising the requested data rate is transmitted periodically. The absolute reference allows base station to determine the exact data rate requested by mobile station. For each time slots between transmissions of the absolute reference, mobile station transmits a relative reference to base station which indicates whether the requested data rate for the upcoming time slot is higher, lower, or the same as the requested data rate for the previous time slot. Periodic transmission of the absolute reference allows base station to determine the requested data rate and ensures that erroneous receptions of relative references do not accumulate. The use of absolute and relative references can reduce the transmission rate of the DRC message to a minimum. In the present invention, to transmit the requested data rate can also be contemplated and are within the scope of the present invention.

#### XVI. Reverse Link Access Channel

[0158] The access channel is used by mobile station to transmit messages to base station during the registration phase. In the exemplary embodiment, the access channel is implemented using a slotted structure which is accessed at random by mobile station. In the exemplary embodiment, the access channel is time multiplexed with the DRC channel.

[0159] In the exemplary embodiment, the access channel transmits messages in access channel capsules. In the exemplary embodiment, the access channel frame format is identical to that specified by the IS-95 standard. The timing is in 26.67 msec frames instead of the 20 msec frames specified by the IS-95 standard. The diagram of an exemplary access channel capsule is shown in FIG. 7B. In the exemplary embodiment, each access channel capsule comprises preamble, one or more message capsules, and padding. Each message capsule comprises message length (MSG LEN), message body, and CRC parity.

## XVIII. Reverse Link NACK Channel

[0160] In the present invention, mobile stations transmit the NACK messages on the data channel. The NACK message is generated for each packet received in error by the mobile station. In the exemplary embodiment, the NACK messages can be transmitted using the Blank and Burst signaling data format as disclosed in the above mentioned Patent No. 5,504,773.

[0161] Although the present invention has been described in the context of a NACK protocol, the protocol can be contemplated and are within the scope of the present invention.

[0162] The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention. The various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without inventive faculty.

## Claims

1. A method of controlling a data rate of a signal transmitted over a wireless channel during a time frame from a base station (4) to a mobile station (6), the time frame comprising a plurality of time slots, the method comprising:
  - receiving a data request message, DRC message, at the base station (4) transmitted from the mobile station (6) and containing an indication of a quality measure of the channel;
  - selecting at the base station a data rate that is based on said indication in the received DRC message;
  - transmitting the signal from the base station (4) during the time frame at said data rate, the indication in the DRC message is based on a pilot signal transmitted through a forward channel from the base station (4), and the DRC message is received at every time slot at the base station (4);
2. The method of claim 1, wherein the DRC message and traffic data are transmitted concurrently on orthogonal quadrature channels.
3. The method of claim 1, wherein the selecting comprises selecting the data rate from among a predetermined set of data rates.
4. The method of claim 1, wherein the selecting comprises selecting a channel coding configuration corresponding to the data rate during the time frame.
5. The method of claim 1, wherein the selecting comprises selecting a packet format corresponding to the data rate.
6. The method of claim 1, wherein the selecting comprises selecting a quantity of user data corresponding to the data rate for transmission during the time frame.
7. A base station (4) configured to transmit a signal to a mobile station (6) during a time frame comprising a plurality of time slots, the base station (4) comprising:
  - means for receiving from the mobile station (6) a data request message, DRC message, containing an indication of a quality measure of the wireless channel;
  - means for selecting a data rate that is based on said indication in the received DRC message;
  - means for transmitting the signal at said data rate, in that the indication in the DRC message is based on a pilot signal transmitted through a forward channel from the base station (4), and the DRC message is received at every time slot at the base station (4);
8. The base station (4) of claim 7, wherein the DRC message and traffic data are transmitted concurrently on orthogonal quadrature channels.
9. The base station (4) of claim 7, wherein the means for selecting comprises means for selecting a data rate from among a predetermined set of data rates.
10. The base station (4) of claim 7, wherein the means for selecting the data rate comprises means for selecting a channel coding configuration corresponding to the data rate.



11. The base station (4) of claim 7, wherein the means for selecting the data rate comprises means for selecting a packet format corresponding to the data rate.

12. The base station (4) of claim 7, wherein the means for selecting the data rate comprises means for selecting a quantity or user data corresponding to the data rate for transmission during the time frame.

13. The base station (4) of claim 7,  
wherein said means for receiving comprises a receiver configured to receive from the mobile station a message containing an indication of said quality measure of the wireless channel; and  
wherein said means for transmitting comprises a transmitter coupled to the receiver and configured to transmit the signal during said time frame at said data rate that is based on the received DRC message.

14. The base station (4) of claim 13, further comprising a selector element (14) coupled to the receiver and configured to select the data rate based on the received DRC message.

15. The base station (4) of claim 14, wherein the selector element (14) is configured to select the data rate from a predetermined set of data rates.

16. The base station (4) of claim 14, wherein the selector element (14) is configured to select a duration for transmission of the signal during the time frame, wherein the selected duration corresponds to the data rate.

17. The base station (4) of claim 14, wherein the selector element (14) is configured to select a packet format for transmission of the signal during the time frame, wherein the selected packet format corresponds to the data rate.

18. The base station (4) of claim 14, wherein the selector element (14) is configured to select a quantity of user data for transmission of the signal during the time frame, wherein the selected quantity of user data corresponds to the data rate.

19. A method of controlling a data rate of a signal received at a mobile station (6) and transmitted to the mobile station (6) during a time frame over a wireless channel, the time frame comprising a plurality of time slots, the method comprising:

transmitting, from the mobile station (6), a data request message, DRC message, to the base station (4) containing an indication of a quality measure of the wireless channel; and  
receiving, at the mobile station (6), the signal at a data rate during the time frame, wherein the data rate is based on the quality measure characterized in that  
the indication in the DRC message is based on a pilot signal transmitted through a forward channel from the base station (4), and the DRC message is transmitted at every time slot from the mobile station (6).

20. The method of claim 19, wherein the DRC message and traffic data are transmitted concurrently over orthogonal quadrature channels.

21. The method of claim 19, wherein the transmitting comprises transmitting information indicative of a carrier-to-interference ratio for the wireless channel.

22. The method of claim 19, wherein the receiving comprises receiving a packet having a packet format corresponding to the data rate.

23. The method of claim 22, wherein the receiving comprises receiving a packet having a packet format corresponding to a predefined quantity of coding bits for transmission during the time frame.

24. The method of claim 22, wherein the receiving comprises receiving a packet having a packet format corresponding to a predefined quantity of user data bits for transmission during the time frame.

25. The method as in claim 19, further comprising:

determining a carrier-to-interference (C/I) ratio of data communications received on a forward link from the base station (4).

26. The method as in claim 19, further comprising:

determining a Bit Error Rate (BER) of data communications received on a forward link.

27. The method as in claim 19, further comprising:

determining a Packet Error Rate (PER) of data communications received on a forward link.

28. The method as in claim 19, wherein transmitting the DRC message comprises:

transmitting the DRC message on a dedicated channel on a reverse link.

29. The method as in claim 19, further comprising:

demodulating data communications received on a traffic channel of a forward link in accordance with a predetermined rate; and  
decoding data communications received on a traffic channel of a forward link in accordance with a predetermined rate.

30. The method as in claim 19, further comprising:

retransmitting the DRC message on a reverse link.

31. A mobile station (6) for receiving a signal during a time frame through a wireless channel from a base station (4) during a time frame comprising a plurality of time slots, the mobile station (6) comprising:

means for transmitting to the base station (4) a data request message, DRC message, containing an indication of a quality measure of the wireless channel; and  
means for receiving from the base station (4) the signal at a data rate during the time frame, wherein the data rate is based on the quality measure characterized in that  
the indication in the DRC message is based on a pilot signal transmitted through a forward channel from the base station (4), and the DRC message is transmitted at every time slot from the mobile station (6).

32. The mobile station (6) of claim 31, wherein the DRC message and traffic data are transmitted concurrently on in-phase and quadrature channels.

33. The mobile station (6) of claim 31, wherein the means for transmitting comprises means for transmitting an indication of a carrier-to-interference ratio for the wireless channel.

34. The mobile station (6) of claim 31, wherein the means for receiving comprises means for determining a packet format of the received signal, wherein the packet format corresponds to the data rate.

35. The mobile station (6) of claim 31, wherein the means for receiving comprises means for determining a channel coding configuration for decoding the signal, wherein the channel coding configuration corresponds to the data rate.

36. The mobile station (6) of claim 31, wherein said means for transmitting comprise a transmitter configured to transmit to the base station (4) a message containing an indication of said quality measure of the wireless channel; and wherein said means for receiving comprise a receiver configured to receive from the base station (4) the signal at said data rate during said time frame, wherein the data rate is based on the quality measure.

37. The mobile station (6) of claim 36, wherein the DRC message containing an indication of a quality measure of the wireless channel is a carrier-to-interference ratio for the wireless channel.

38. The mobile station (6) as in claim 31, further comprising:

means for determining a Carrier-to-Interference (C/I) ratio of data communications received on a forward channel.

39. The mobile station (6) as in claim 31, further comprising:

means for determining a Bit Error Rate (BER) of data communications received on a forward link

40. The mobile station (6) as in claim 31, further comprising:

means for determining a Packet Error Rate (PER) of data communications received on a forward

41. The mobile station (6) as in claim 31, further comprising:

means for transmitting the DRC message on a dedicated channel on a reverse link.

42. The mobile station (6) as in claim 31, further comprising:

means for demodulating data communications received on a traffic channel of a forward link in accordance with the data rate; and

means for decoding data communications received on a traffic channel of a forward link in accordance with the data rate.

#### Patentansprüche

1. Verfahren zum Steuern einer Datenrate eines Signals, das während eines Zeitfensters über einen Kanal von einer Basisstation (4) an eine Mobilstation (6) übertragen wird, wobei das Zeitfenster einen Zeitschlitz umfasst, das Verfahren aufweisend:

Empfangen einer Datenanfragenachrichtigung (DRC-Nachricht), bei der Basisstation (4), die von der Mobilstation (6) übertragen wurde und einen Hinweis auf ein Qualitätsmaß des Kanals enthält;

Auswählen einer Datenrate bei der Basisstation basierend auf dem Hinweis in der DRC-Nachricht, die den Empfangen des Signals von der Basisstation (4) während des Zeitfensters darstellt, und Kennzeichnen, dass

der Hinweis in der DRC-Nachricht auf einem Pilotsignal basiert, das durch einen Vorwortsverbindungsprozess von der Basisstation (4) übertragen wurde, und dass die DRC-Nachricht jedem Zeitschlitz von der Basisstation (4) empfangen wird.

2. Verfahren nach Anspruch 1, wobei die DRC-Nachricht und Verkehrsdaten gleichzeitig über einen Kanal in- und einem Quadraturkanal übertragen werden.

3. Verfahren nach Anspruch 1, wobei das Auswählen ein Auswählen der Datenrate aus einer vorbestimmten Menge von Datenraten umfasst.

4. Verfahren nach Anspruch 1, wobei das Auswählen ein Auswählen einer Kanalkodierungskonfiguration aus einer vorbestimmten Menge von Kanalkodierungskonfigurationen basierend auf der Datenrate während des Zeitfensters umfasst.

5. Verfahren nach Anspruch 1, wobei das Auswählen umfasst Auswählen eines Paketformats entsprechend der Datenrate.

6. Verfahren nach Anspruch 1, wobei das Auswählen umfasst Auswählen einer Menge von Anwenderdaten entsprechend der Datenrate zum Übertragen während des Zeitfensters.

7. Basisstation (4), konfiguriert zum Übertragen eines Signals an eine Mobilstation (6) während eines Zeitfensters über einen drahtlosen Kanal, wobei das Zeitfenster eine Mehrzahl von Zeitschlitzen umfasst, wobei das Zeitfenster einen Zeitschlitz umfasst, der aufweist:

Mittel zum Empfangen einer Datenanfragenachrichtigung (DRC-Nachricht), von der Mobilstation (6), wobei die DRC-Nachricht einen Hinweis auf ein Qualitätsmaß des drahtlosen Kanals enthält;

Mittel zum Auswählen einer Datenrate basierend auf dem Hinweis in der DRC-Nachricht, die den Empfangen der DRC-Nachricht darstellt, und

Mittel zum Übertragen des Signals mit der Datenrate, gekennzeichnet, dass

die Hinweise in der DRC-Nachricht auf einem Pilotsignal basieren, das durch einen Vorwortsverbindungsprozess von der Basisstation (4) übertragen wurde, und dass die DRC-Nachricht jedem Zeitschlitz von der Basisstation (4) empfangen wird.

Pilotkanal von der Basisstation empfangen wurde, und dass die DRFC in jedem Zeitschlitz von der Basisstation (4) empfangen wird.

8. Basisstation (4) nach Anspruch 7, wobei die Mittel zum Auswählen der Datenrate Mittel zum Auswählen der Datenrate auf einem In-Kanal und einem Quadranten übertragen werden.
9. Basisstation (4) nach Anspruch 7, wobei die Mittel zum Auswählen der Datenrate Mittel zum Auswählen der Datenrate auf einer vorbestimmten Menge von Datenraten umfassen.
10. Basisstation (4) nach Anspruch 7, wobei die Mittel zum Auswählen der Datenrate Mittel zum Auswählen der Datenrate auf einer Kanalkodierungskonfiguration entsprechend der Datenrate umfassen.
11. Basisstation (4) nach Anspruch 7, wobei die Mittel zum Auswählen der Datenrate Mittel zum Auswählen der Datenrate auf einem Paketformats entsprechend der Datenrate umfassen.
12. Basisstation (4) nach Anspruch 7, wobei die Mittel zum Auswählen der Datenrate Mittel zum Auswählen der Datenrate auf einer an Anwenderdaten entsprechend der Datenrate zur Übertragung während des Zeitfensters umfassen.
13. Basisstation (4) nach Anspruch 7, wobei die Mittel zum Empfangen einen Empfänger umfassen, der zum Empfangen der DRC der Mobilstation konfiguriert ist, wobei die Mittel zum Übertragen einen Sender umfassen, der mit dem Empfänger verbunden ist und zum Übertragen des Signals während des Zeitfensters mit der Datenrate konfiguriert ist, die auf dem Empfänger basiert.
14. Basisstation (4) nach Anspruch 13, weiterhin aufweisend ein Auswahlelement (14), das mit dem Empfänger verbunden ist und zum Auswählen der Datenrate basierend auf der auf dem Empfänger konfiguriert ist.
15. Basisstation (4) nach Anspruch 14, wobei das Auswahlelement (14) zum Auswählen der Datenrate auf einer bestimmten Menge von Datenraten konfiguriert ist.
16. Basisstation (4) nach Anspruch 14, wobei das Auswahlelement (14) zum Auswählen einer Kanalkodierungskonfiguration zum Übertragen des Signals während des Zeitfensters konfiguriert ist, wobei die ausgewählte Kanalkodierungskonfiguration der Datenrate entspricht.
17. Basisstation (4) nach Anspruch 14, wobei das Auswahlelement (14) zum Auswählen eines Paketformats zum Übertragen des Signals während des Zeitfensters konfiguriert ist, wobei das ausgewählte Paketformat der Datenrate entspricht.
18. Basisstation (4) nach Anspruch 14, wobei das Auswahlelement (14) zum Auswählen einer Menge von Datenraten zur Übertragung des Signals während des Zeitfensters konfiguriert ist, wobei die ausgewählte Menge von Datenraten der Datenrate entspricht.
19. Verfahren zum Steuern einer Datenrate eines Signals, das von einer Mobilstation (6) empfangen wird, wobei die Basisstation (4) an die Mobilstation (6) während eines Zeitfensters über einen drahtlosen Kanal überträgt, wobei das Zeitfenster eine Mehrzahl von Zeitschlitzten umfasst, das Verfahren aufweisend:
  - a) Übertragen einer Datenanfragenachrichte, die von der Mobilstation (6) an die Basisstation (4) überträgt, wobei die Nachricht einen Hinweis auf ein Qualitätsmaß des drahtlosen Kanals enthält; und
  - b) Empfangen des Signals bei der Mobilstation mit einer Datenrate während des Zeitfensters, wobei die Datenrate auf dem Qualitätsmaß basierend gekennzeichnet ist, dass der Hinweis in der Nachricht auf einem Pilotensignal basiert, das durch einen Vorübertragungsprozess von der Basisstation (4) übertragen wurde, und wobei die DRC jedem Zeitschlitz von der Mobilstation (6) übertragen wird.
20. Verfahren nach Anspruch 19, wobei die DRC und Verkehrsdaten gleichzeitig auf einem In-Kanal übertragen werden.

und einem Quadratkanal übertragen werden.

21. Verfahren nach Anspruch 19, wobei das Übertragen ein Übertragen von Informationen hinweisend auf  
zu-Interferenzverhältnis für den drahtlosen Kanal umfasst.

22. Verfahren nach Anspruch 19, wobei das Empfangen ein Empfangen eines Paketes mit einem Paketformat  
wobei das Paketformat der Datenrate entspricht.

23. Verfahren nach Anspruch 22, wobei das Empfangen ein Empfangen eines Paketes mit einem Paketformat  
das eine vorbestimmte Menge von Bits zur Übertragung während des Zeitfensters umfasst.

24. Verfahren nach Anspruch 22, wobei das Empfangen ein Empfangen eines Paketes mit einem Paketformat  
das eine vorbestimmte Menge von Anwenderdatenbits zum Übertragen während des Zeitfensters umfasst.

25. Verfahren nach Anspruch 19, weiterhin aufweisend:

Bestimmen eines Träger-Interferenzverhältnisses (C/I) von Datenmitteilungen, die auf einer Vorwirts-  
bindung empfangen wurden.

26. Verfahren nach Anspruch 19, weiterhin aufweisend:

Bestimmen einer Fehler-Rate (BER) von Datenmitteilungen, die auf einer Vorwirtsverbindung empfangen  
wurden.

27. Verfahren nach Anspruch 19, weiterhin aufweisend:

Bestimmen einer Paket-Rate (PER) von Datenmitteilungen, die auf einer Vorwirtsverbindung empfangen  
wurde.

28. Verfahren nach Anspruch 19, wobei das Übertragen ein Übertragen eines Nachrichtens umfasst:

Übertragen der Nachricht auf einem bestimmten Kanal auf einer Rückwirtsverbindung.

29. Verfahren nach Anspruch 19, weiterhin aufweisend:

Demodulieren von Datenmitteilungen, die auf einem Verkehrskanal einer Vorwirtsverbindung in  
Empfang mit der Datenrate empfangen wurden; und  
Decodieren von Datenmitteilungen, die auf einem Verkehrskanal einer Vorwirtsverbindung in Empfang  
mit der Datenrate empfangen wurden.

30. Verfahren nach Anspruch 19, weiterhin aufweisend:

erneutes Übertragen der Nachricht auf einer Rückwirtsverbindung.

31. Mobilstation (6) zum Empfangen eines Signals während eines Zeitfensters über einen drahtlosen Kanal  
Basisstation (4) wobei das Zeitfenster eine Mehrzahl von Zeitschlitzten umfasst, wobei die Mobilstation

Mittel zum Übertragen einer Datenanfrage an die Basisstation, wobei die Nachricht einen Hinweis auf ein Qualitätsmaß des drahtlosen Kanals enthält; und  
Mittel zum Empfangen des Signals mit einer Datenrate während des Zeitfensters von der Basisstation,  
die Datenrate auf dem Qualitätsmaß basiert, gekennzeichnet, dass  
der Hinweis in der Nachricht auf einem Pilotensignal basiert, das durch einen Vorwirtsverbindung  
von der Basisstation (4) übertragen wurde und wobei die Nachricht jedem Zeitschlitz von der Mobilstation  
(6) übertragen wird.

32. Mobilstation (6) nach Anspruch 31, wobei die Nachricht und Verkehrsdaten gleichzeitig auf einem In-  
Kanal und einem Quadratkanal übertragen werden.

33. Mobilstation nach Anspruch 31, wobei die Mittel zum Übertragen Mittel zum Übertragen von Informationen, die auf ein Träger-Interferenzverhältnis des drahtlosen Kanals hinweisen.

34. Mobilstation (6) nach Anspruch 31, wobei die Mittel zum Empfangen Mittel zum Bestimmen eines Parameters des empfangenen Signals umfassen, wobei das Paketformat der Datenrate entspricht.

35. Mobilstation (6) nach Anspruch 31, wobei die Mittel zum Empfangen Mittel zum Bestimmen einer Kanal-Konfiguration zum Decodieren des Signals umfassen, wobei die Kanalkodierungskonfiguration der Datenrate entspricht.

36. Mobilstation (6) nach Anspruch 31, wobei die Mittel zum Übertragen einen Sender umfassen, der zum Übertragen der DRC-Basisstation konfiguriert ist, wobei die Mittel zum Empfangen einen Empfänger umfassen, der konfiguriert ist zum Empfangen der Datenrate während des Zeitfensters von der Basisstation (4), wobei die Datenrate auf dem Qualitätsmaß des drahtlosen Kanals basiert.

37. Mobilstation nach Anspruch 36, wobei die Mittel zum Übertragen einen Hinweis auf ein Qualitätsmaß des drahtlosen Kanals enthalten, der auf ein Träger-Interferenzverhältnis des drahtlosen Kanals umfasst.

38. Mobilstation nach Anspruch 31, weiterhin aufweisend:

Mittel zum Bestimmen eines Träger-Interferenzverhältnisses (C/I) von Datenmitteilungen, die auf einer Vorwertsverbindung empfangen wurden.

39. Mobilstation (6) nach Anspruch 31, weiterhin aufweisend:

Mittel zum Bestimmen einer Bit-Fehlerrate (BER) von Datenmitteilungen, die auf einer Vorwertsverbindung empfangen wurden.

40. Mobilstation (6) nach Anspruch 31, weiterhin aufweisend:

Mittel zum Bestimmen einer Paket-Fehlerrate (PER) von Datenmitteilungen, die auf einer Vorwertsverbindung empfangen wurden.

41. Mobilstation (6) nach Anspruch 31, weiterhin aufweisend:

Mittel zur Übertragung der DRC auf einem bestimmten Kanal auf einer Rückwertsverbindung.

42. Mobilstation (6) nach Anspruch 31, weiterhin aufweisend:

Mittel zum Demodulieren von Datenmitteilungen, die auf einem Verkehrskanal einer Vorwertsverbindung mit der Datenrate empfangen wurden; und Mittel zum Decodieren von Datenmitteilungen, die auf einem Verkehrskanal einer Vorwertsverbindung mit der Datenrate empfangen wurden.

## Revendications

1. Un procédé pour contrôler un débit de données d'un signal émis sur un canal sans fil durant une transmission depuis une station de base (4) vers une station mobile (6), la trame temporelle comprenant une période temporelle, le procédé comprenant :

recevoir un message de requête de données, message DRC, la station de base (4) émet depuis la station mobile (6) et contenant une indication d'une mesure de qualité du canal ;

sélectionner le message DRC ;

émettre le signal depuis la station de base (4) pendant la trame temporelle caractérisée par le débit de données en ce que

l'indication dans le message DRC est basée sur un signal pilote émis via un canal pilote de

la station de base (4), et le message DRC est reçu chaque crøneau temporel la station de

2. Le procédé de la revendication 1, dans lequel le message DRC et des données de trafic sont transmis sur des canaux en phase et en quadrature.

3. Le procédé de la revendication 1, dans lequel la sélection comprend la sélection du débit de ensemble prédéterminé de bits de données.

4. Le procédé de la revendication 1, dans lequel la sélection comprend la sélection d'une configuration de canal correspondant au débit de données pendant la trame temporelle.

5. Le procédé de la revendication 1, dans lequel la sélection comprend la sélection d'un format de paquet au débit de données.

6. Le procédé de la revendication 1, dans lequel la sélection comprend la sélection d'une quantité de données correspondant au débit de données pour transmission durant la trame temporelle.

7. Une station de base (4) configurée pour émettre un signal vers une station mobile (6) pendant un intervalle de temps sur un canal sans fil, la trame temporelle comprenant une pluralité de crøneaux temporels, la trame temporelle comprenant :

des moyens de réception depuis la station mobile (6) d'un message de requête de données, message contenant une indication d'une mesure de qualité du canal sans fil ;  
des moyens de sélection d'un débit de données qui est basé sur ladite indication dans le message ;  
des moyens d'émission du signal audit débit de données,

caractérisée en ce que

l'indication dans le message DRC est basée sur un signal pilote transmis via un canal pilote de la station de base (4), et le message DRC est reçu chaque crøneau temporel la station de base

8. La station de base (4) de la revendication 7, dans laquelle le message DRC et des données de trafic sont transmis concurremment sur des canaux en phase et en quadrature.

9. La station de base (4) de la revendication 7, dans laquelle les moyens de sélection comprennent la sélection du débit de données parmi un ensemble prédéterminé de bits de données.

10. La station de base (4) de la revendication 7, dans laquelle les moyens de sélection du débit de données comprennent des moyens de sélection d'une configuration de codage de canal correspondant au débit de données.

11. La station de base (4) de la revendication 7, dans laquelle les moyens de sélection du débit de données comprennent des moyens de sélection d'un format de paquet correspondant au débit de données.

12. La station de base (4) de la revendication 7, dans laquelle les moyens de sélection du débit de données comprennent des moyens de sélection d'une quantité de données utilisateur correspondant au débit de données pendant la trame temporelle.

13. La station de base (4) de la revendication 7, dans laquelle lesdits moyens de réception comprennent un récepteur configuré pour recevoir de la station mobile (6) le message DRC contenant une indication de ladite mesure de qualité du canal sans fil ; et dans laquelle lesdits moyens d'émission comprennent un émetteur couplé au récepteur et configuré pour émettre le signal durant ladite trame temporelle audit débit de données qui est basé sur le message DRC.

14. La station de base (4) de la revendication 13, comprenant en outre un élément sélecteur (14) configuré pour sélectionner le débit de données sur la base du message DRC.

15. La station de base (4) de la revendication 14, dans laquelle l'élément sélecteur (14) est configuré pour sélectionner le débit de données parmi un ensemble prédéterminé de bits de données.

16. La station de base (4) de la revendication 14, dans laquelle l'élément sélecteur (14) est confi-  
une configuration de codage de canal pour omission du signal pendant la trame temporelle, dans  
figuration de codage de canal sélectionnée correspond au débit de données.

17. La station de base (4) de la revendication 14, dans laquelle l'élément sélecteur (14) est confi-  
un format de paquet pour omission du signal durant la trame temporelle, dans laquelle le format de  
correspond au débit de données.

18. La station de base (4) de la revendication 14, dans laquelle l'élément sélecteur (14) est confi-  
une quantité de données utilisateur pour omission du signal durant la trame temporelle, dans l  
sélectionnée de données utilisateur correspond au débit de données.

19. Un procédé pour contrôler un débit de données d'un signal reçu par une station mobile (6) émis  
de base (4) vers la station mobile (6) durant une trame temporelle sur un canal sans fil, la trame  
une pluralité de crôneaux temporels, le procédé comprenant :

l'omission, depuis la station mobile (6), d'un message de requête de données, message DRC,  
de base (4) contenant une indication d'une mesure de qualité du canal sans fil ; et  
la réception, la station mobile (6), du signal un débit de données durant la trame tem  
données étant basé sur la mesure de qualité en ce que

l'indication dans le message DRC est basée sur un signal pilote transmis via un canal pil  
depuis la station de base (4), et le message DRC est émis chaque crôneau temporel dep  
mobile (6).

20. Le procédé de la revendication 19, dans lequel le message DRC et des données de trafic sont t  
remment sur des canaux en phase et en quadrature.

21. Le procédé de la revendication 19, dans lequel l'omission comprend l'omission d'informations  
rapport porteuse et interférence pour le canal sans fil.

22. Le procédé de la revendication 19, dans lequel la réception comprend la réception d'un paquet a  
paquet, dans lequel le format de paquet correspond au débit de données.

23. Le procédé de la revendication 22, dans lequel la réception comprend la réception d'un paquet a  
paquet qui inclut une quantité prédéfinie de bits de codage pour omission durant la trame temp

24. Le procédé de la revendication 22, dans lequel la réception comprend la réception d'un paquet a  
paquet qui inclut une quantité prédéfinie de bits de données utilisateur pour transmission duran

25. Le procédé de la revendication 19, comprenant en outre :

la détermination d'un rapport porteuse et interférence (C/I) des communications de données reçues sur  
liaison aller.

26. Le procédé de la revendication 19, comprenant en outre :

la détermination d'un taux d'erreurs de bits (BER) des communications de données reçues sur u

27. Le procédé de la revendication 19, comprenant en outre :

la détermination d'un taux d'erreurs de paquet (PER) des données de communication reçues sur u

28. Le procédé de la revendication 19, dans lequel l'omission du message DRC comprend :

l'omission du message DRC sur un canal dédié sur une liaison retour.

29. Le procédé de la revendication 19, comprenant en outre :



la d'omulation des communications de donn'es re ues sur un canal de trafic d'une liaison aller  
au d'obit de donn'es ; et  
le d'ocodage des communications de donn'es re ues sur un canal de trafic d'une liaison aller  
au d'obit de donn'es.

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30. Le proc'd de la revendication 19, comprenant en outre :

la retransmission du message DRC sur une liaison retour.

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31. Une station mobile (6) pour recevoir un signal pendant une trame temporelle via un canal sans fil  
de base (4), la trame temporelle comprenant une pluralit' de cr'oneaux temporels, la station mobi

des moyens d'omission vers la station de base (4) d'un message de requ'te de donn'es, mes  
contenant une indication d'une mesure de qualit' du canal sans fil ; et

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des moyens d'omission depuis la station de base (4) du signal un d'obit de donn'es durant la  
o' le d'obit de donn'es est bas' sur la mesure de qualit',

caract'ris' en ce : que

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l'indication dans le message DRC est bas'e sur un signal pilote transmis via un canal pilo  
depuis la station de base (4), et le message DRC est omis chaque cr'oneau temporel depuis la s

32. La station mobile (6) de la revendication 31, dans laquelle le message DRC et les donn'es de t  
concurrentement sur des canaux en phase et en quadrature.

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33. La station mobile (6) de la revendication 31, dans laquelle les moyens d'omission comprennent  
omettre une information indicatrice d'un rapport ~~interférence~~ pour le canal sans fil.

34. La station mobile (6) de la revendication 31, dans laquelle les moyens de r'ception comprennent  
d'terminer un format de paquet du signal re u, o' le format de paquet correspond au d'obit de d

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35. La station mobile (6) de la revendication 31, dans laquelle les moyens de r'ception comprennent  
d'terminer une configuration de codage de canal pour d'ocoder le signal, o' la configuration de  
correspond au d'obit de donn'es.

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36. La station mobile (6) de la revendication 31,  
dans laquelle lesdits moyens d'omission comprennent un o'metteur configur' pour o'mettre vers la  
(4) le message DRC contenant une indication de ladite mesure de qualit' du canal sans fil ; et  
dans laquelle lesdits moyens de r'ception comprennent un r'cepteur configur' pour recevoir de l  
(4) le signal audit d'obit de donn'es durant ladite trame temporelle, o' le d'obit de donn'es es  
de qualit'.

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37. La station mobile (6) de la revendication 36, dans laquelle le message DRC contenant une indica  
de qualit' inclut un rapport ~~interférence~~ pour le canal sans fil.

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38. La station mobile (6) de la revendication 31, comprenant en outre :

des moyens de d'termination d'un rapport ~~interférence~~ (C/I) des communications de donn'es  
re ues sur une liaison aller.

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39. La station mobile (6) de la revendication 31, comprenant en outre :

des moyens de d'termination d'un taux d'erreurs de bits (BER) des communications de donn'es  
une liaison aller.

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40. La station mobile (6) de la revendication 31, comprenant en outre :

des moyens de d'termination d'un taux d'erreurs de paquet (PER) des donn'es de communication

une liaison aller.

41. La station mobile (6) de la revendication 31, comprenant en outre :

5 des moyens d'omission du message DRC sur un canal dédié sur une liaison retour.

42. La station mobile (6) de la revendication 31, comprenant en outre :

10 des moyens de modulation des communications de données reçues sur un canal de trafic d'une  
conformément au débit de données ; et  
des moyens de décodage des communications de données reçues sur un canal de trafic d'une  
conformément au débit de données.

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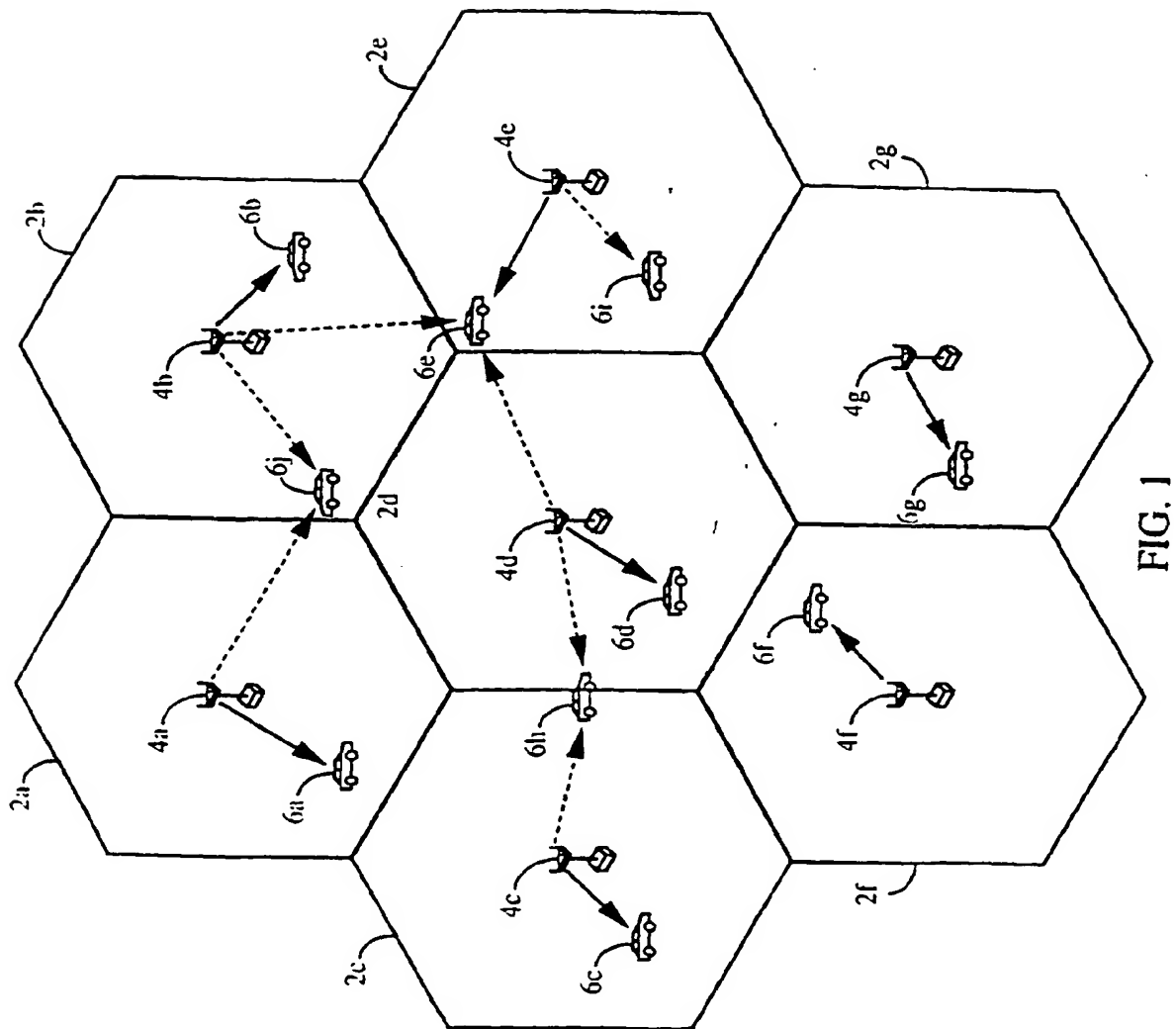


FIG. 1

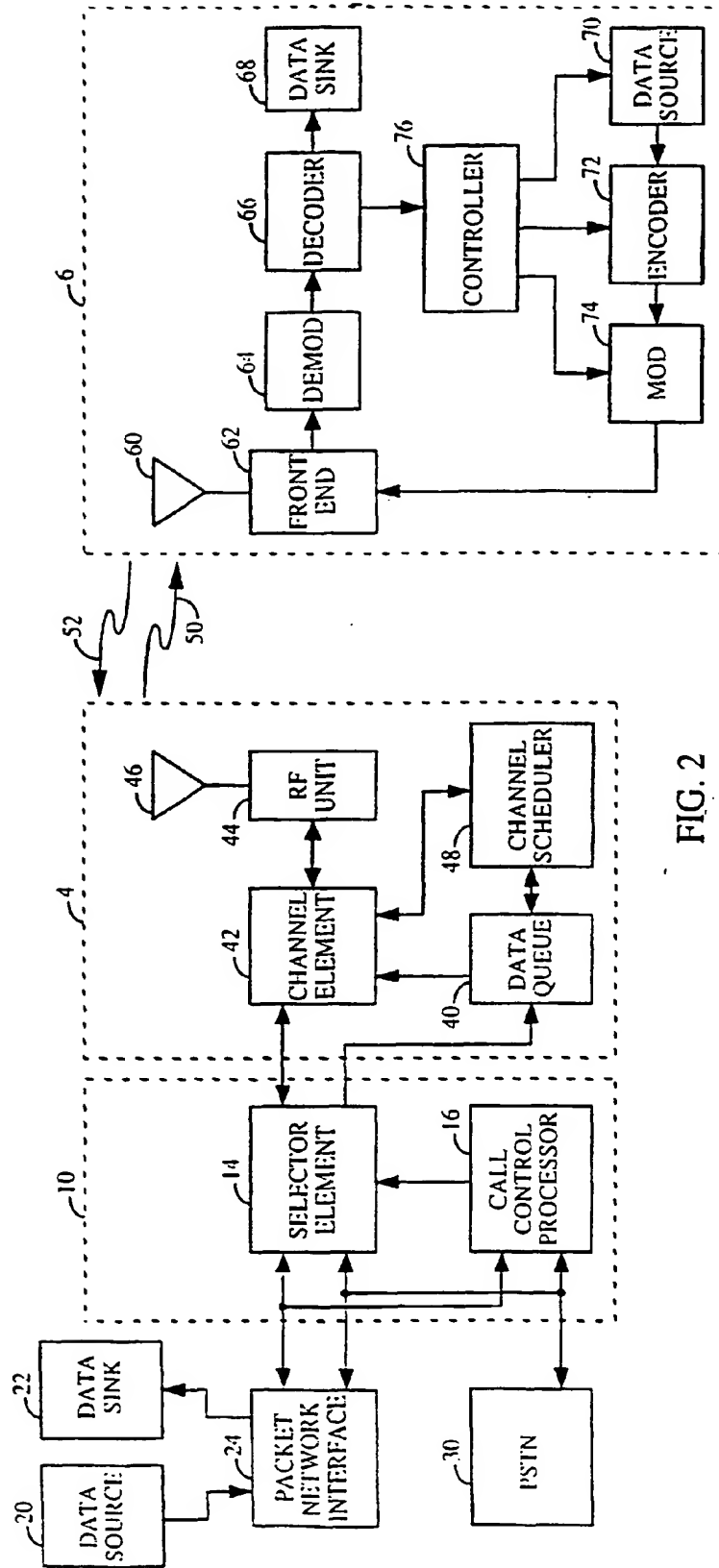


FIG. 2

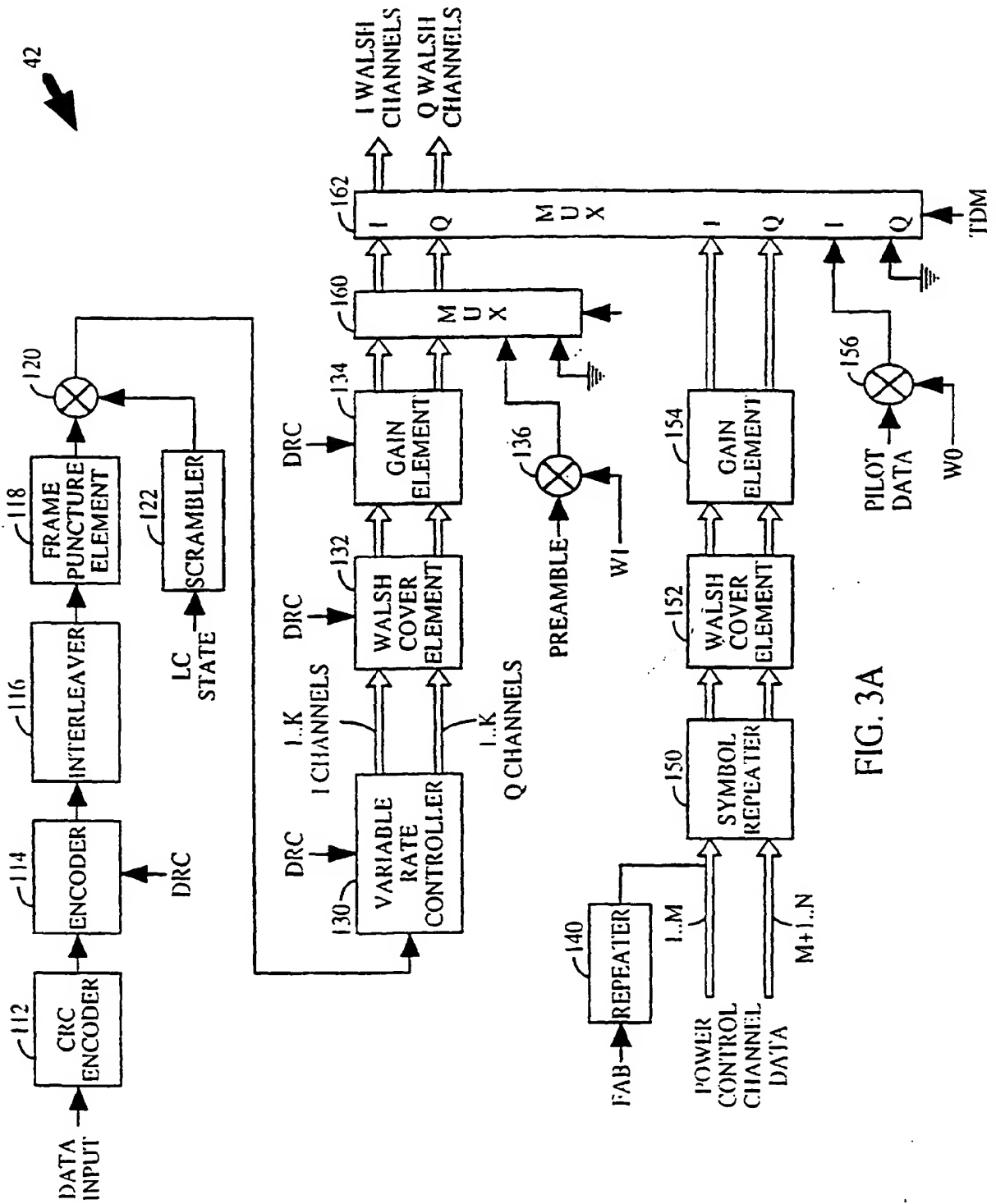


FIG. 3A

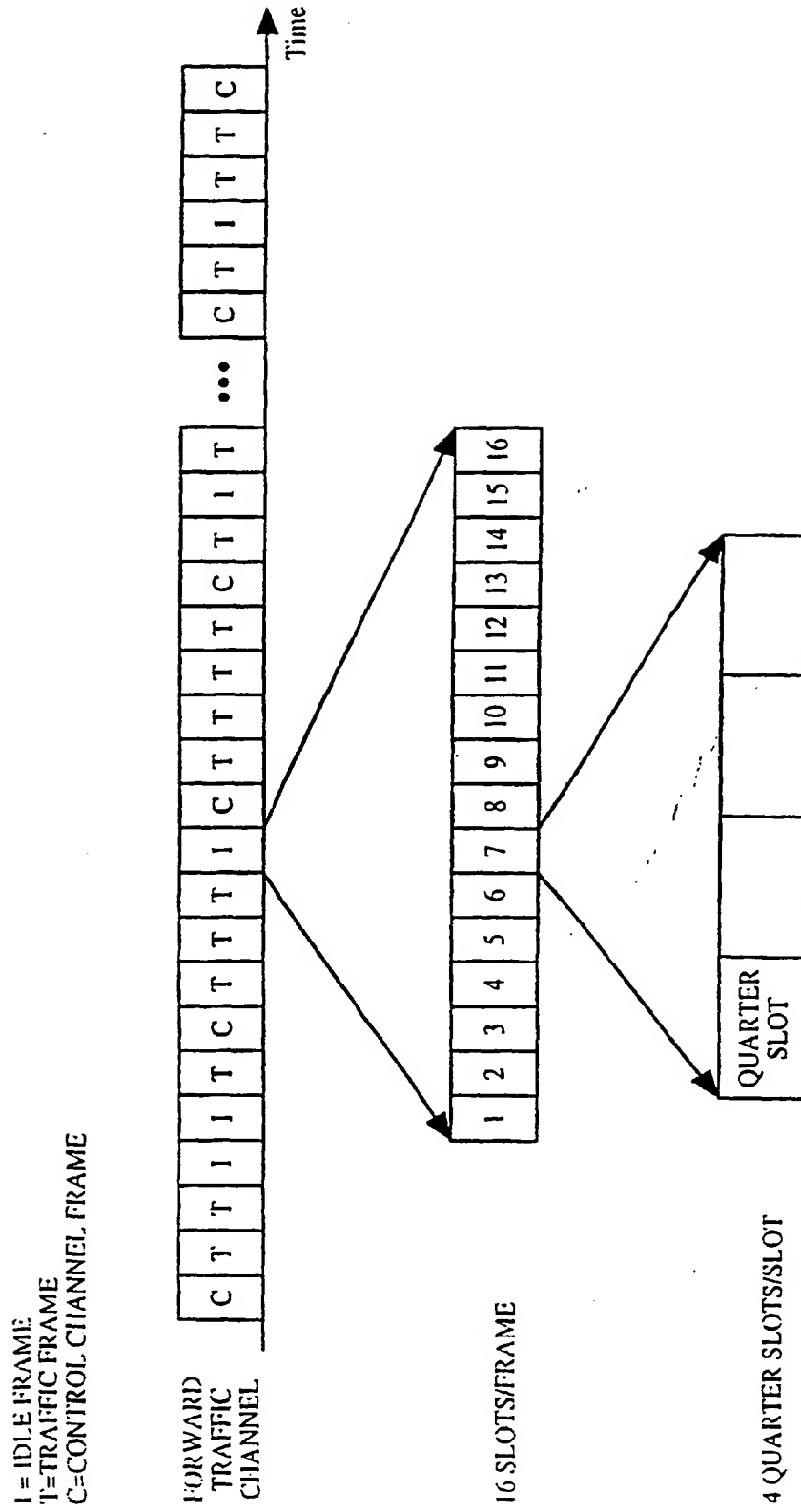


FIG. 4A

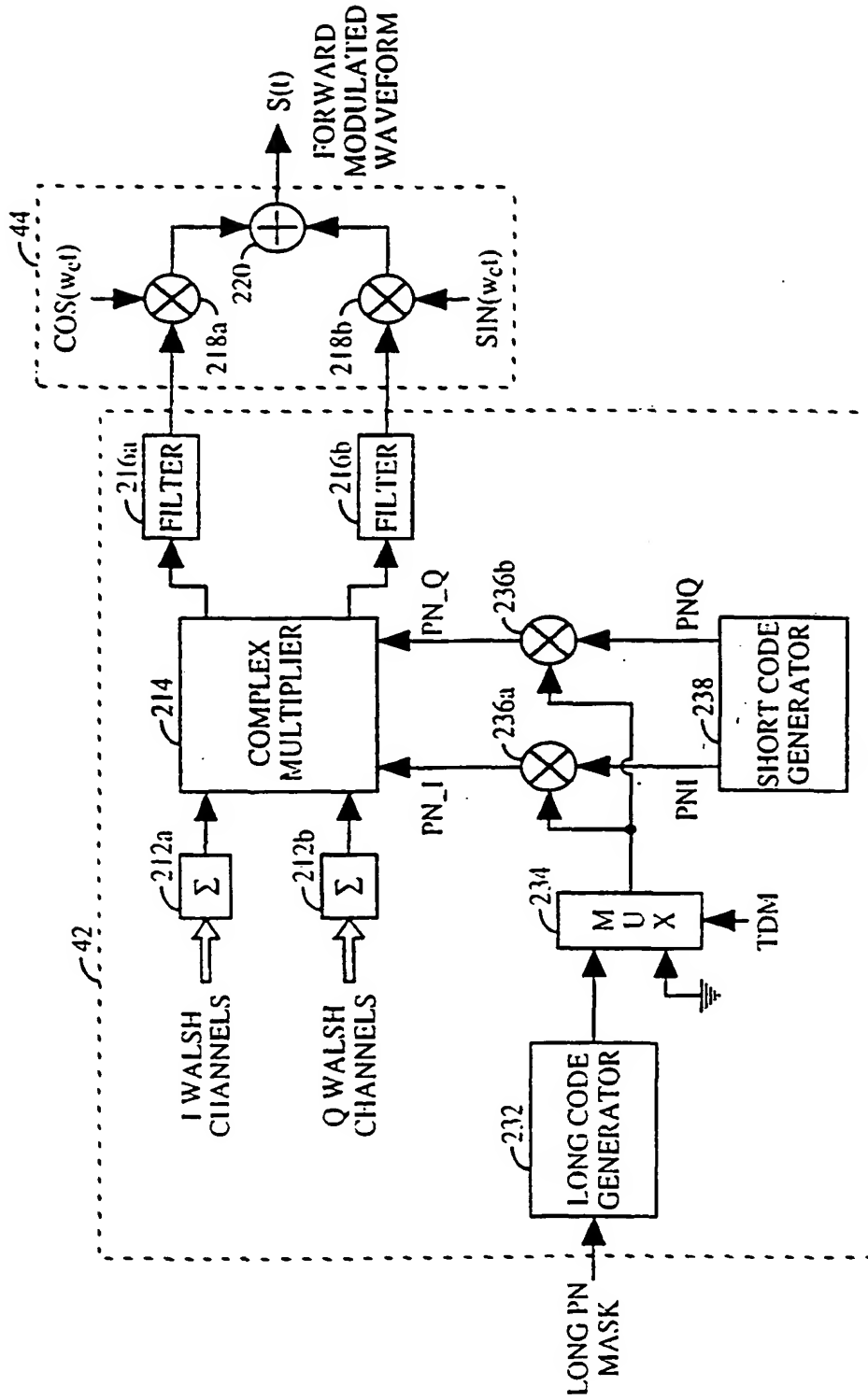
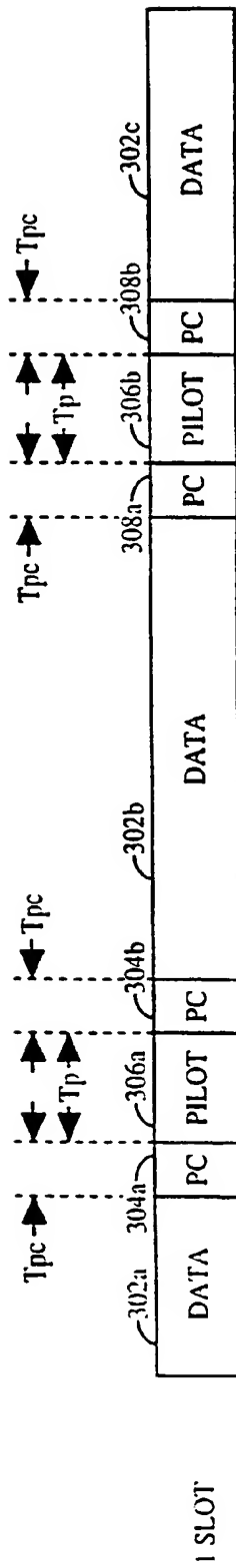


FIG. 3B



FORWARD  
TRAFFIC  
CHANNEL

POWER  
CONTROL  
CHANNEL

PILOT  
CHANNEL

FIG. 4B

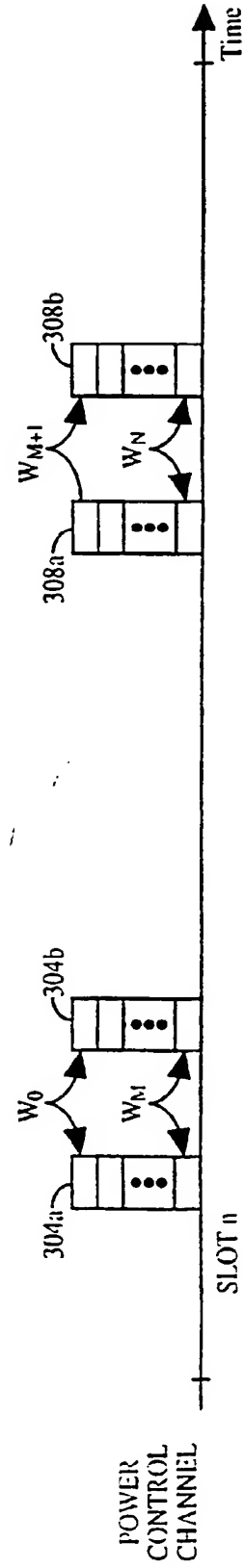


FIG. 4C



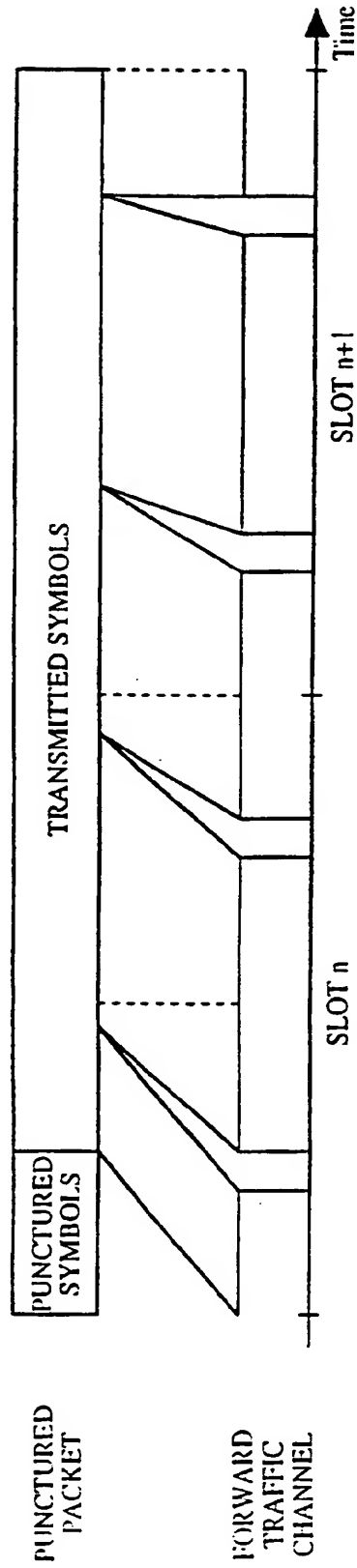


FIG. 4D

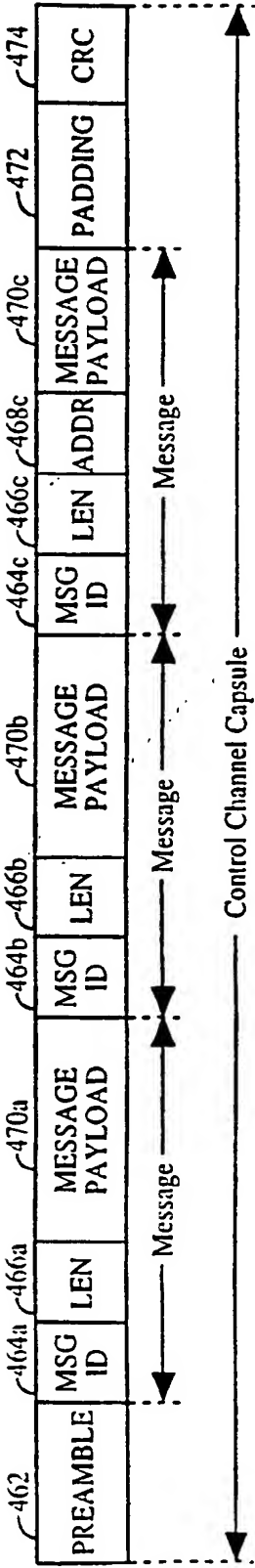
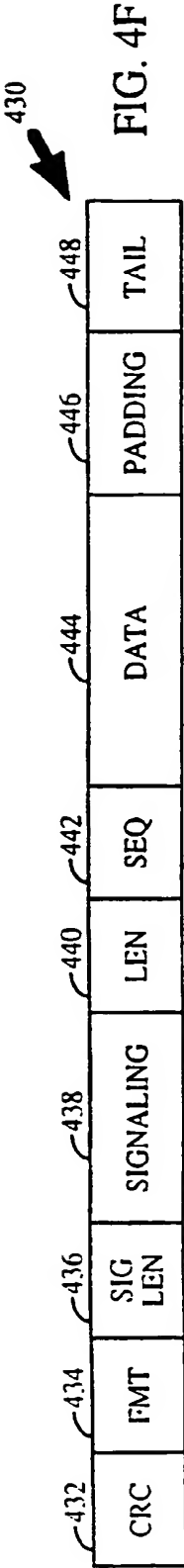
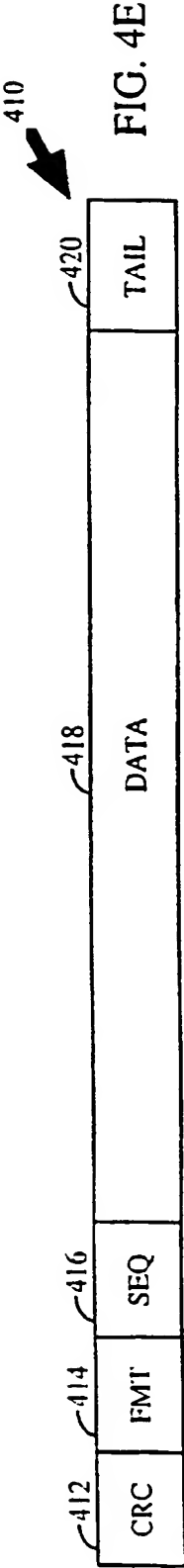


FIG. 4G

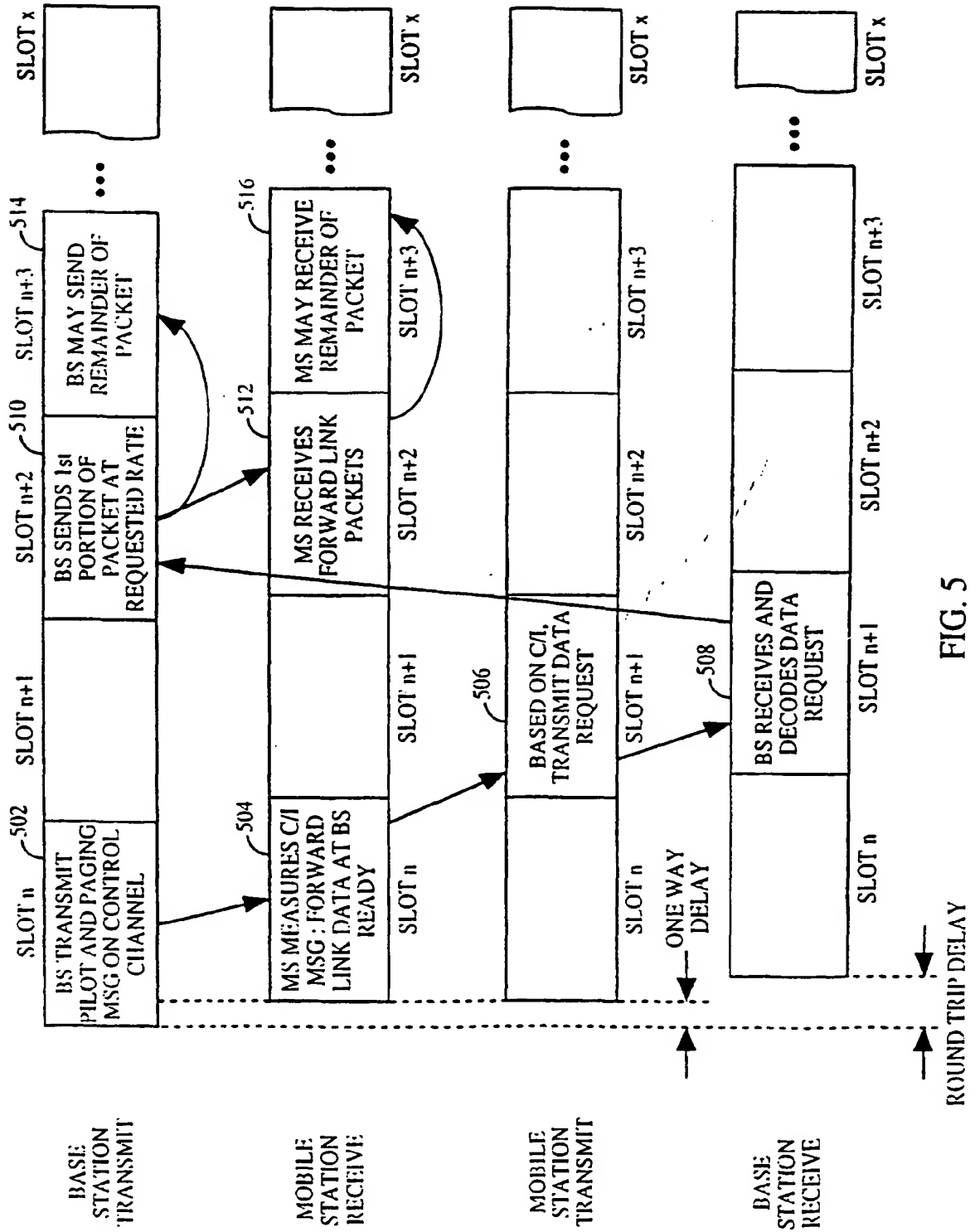


FIG. 5

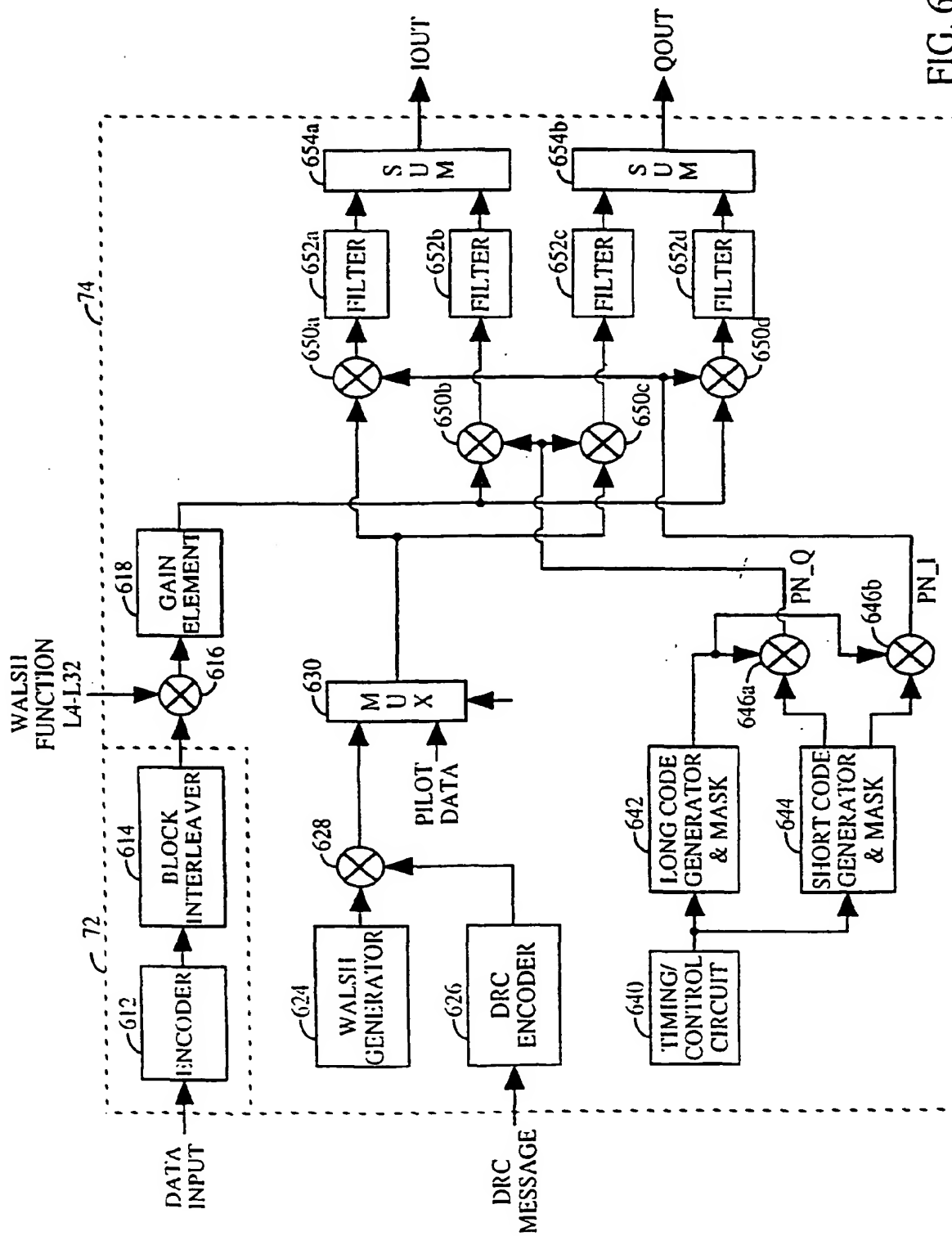


FIG. 6

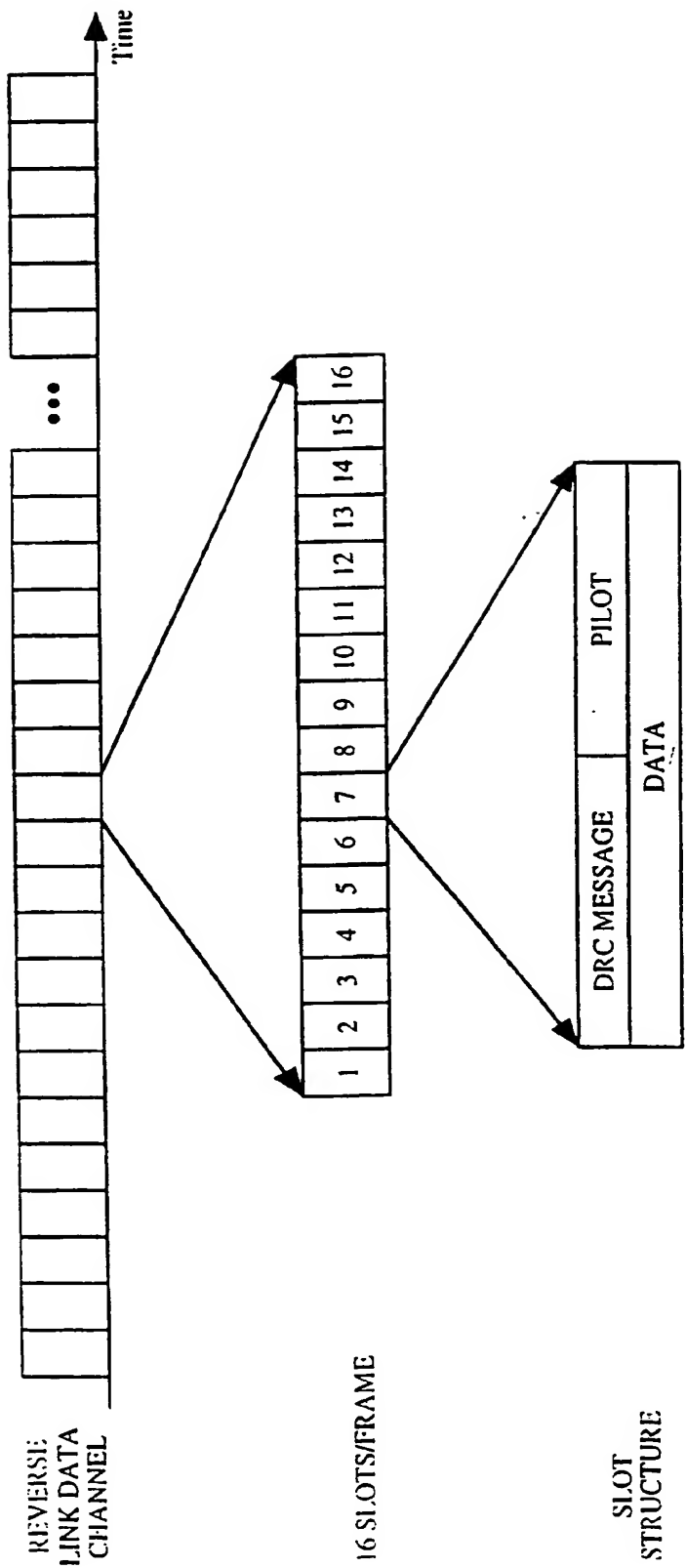


FIG. 7A

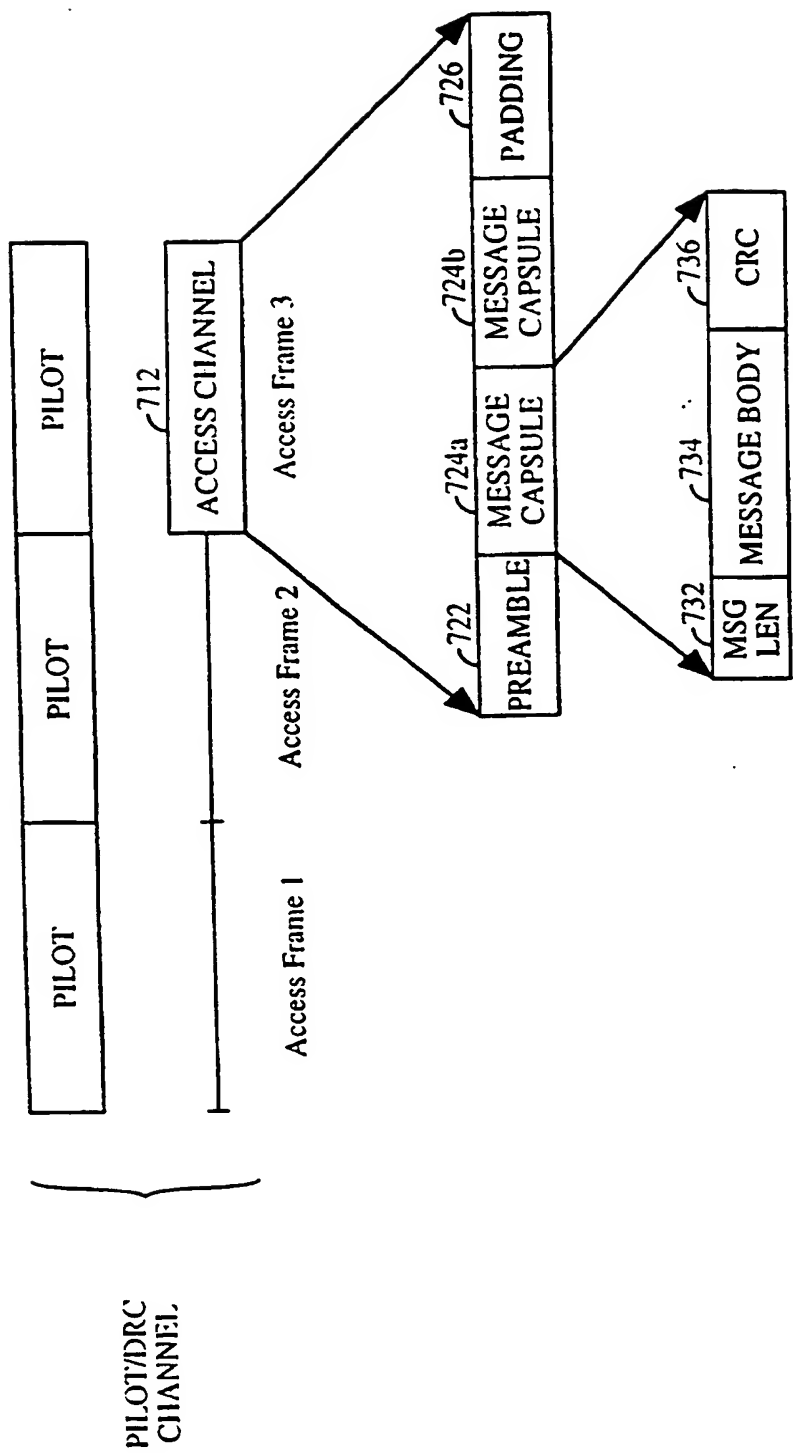


FIG. 7B

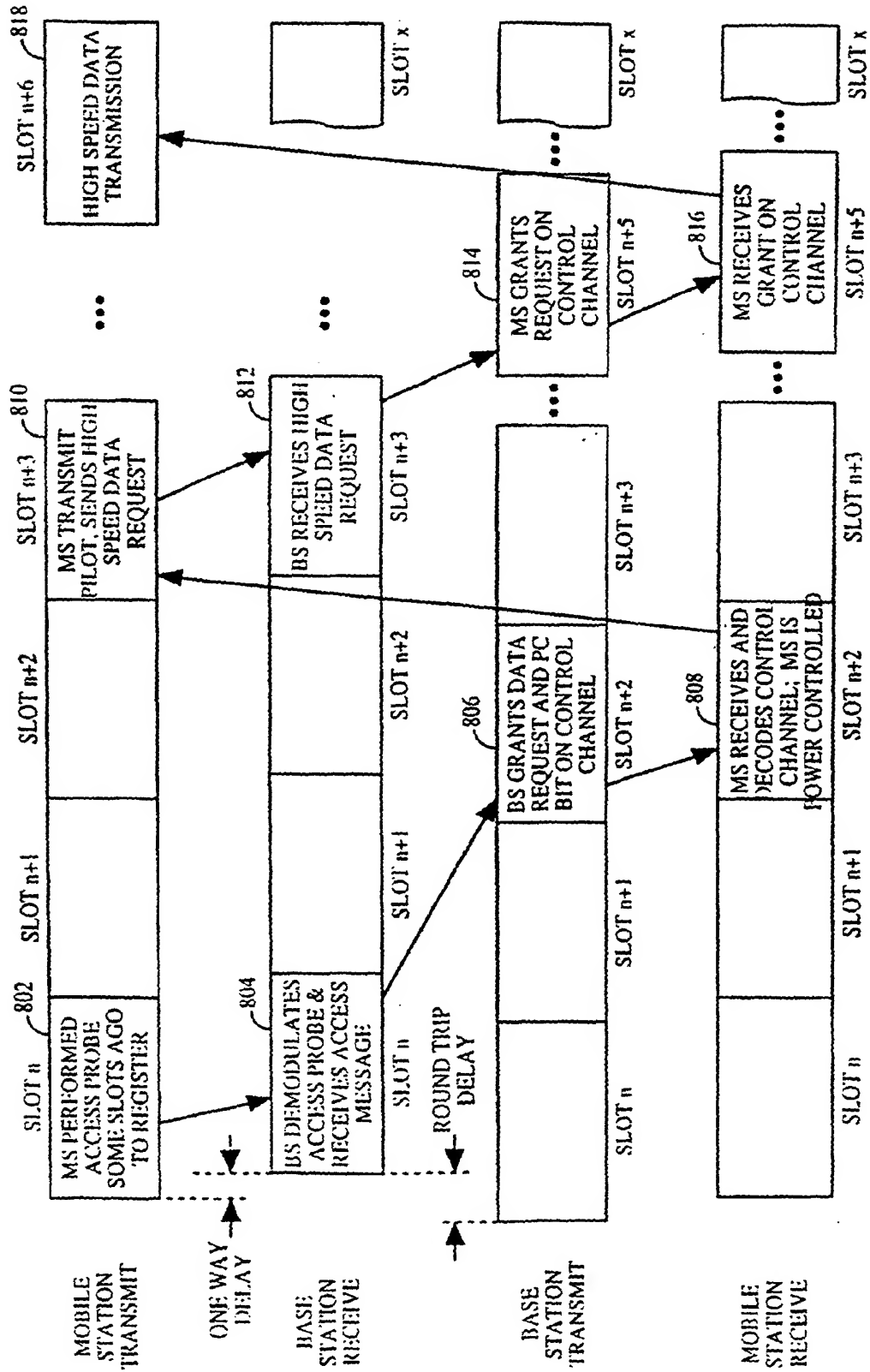


FIG. 8

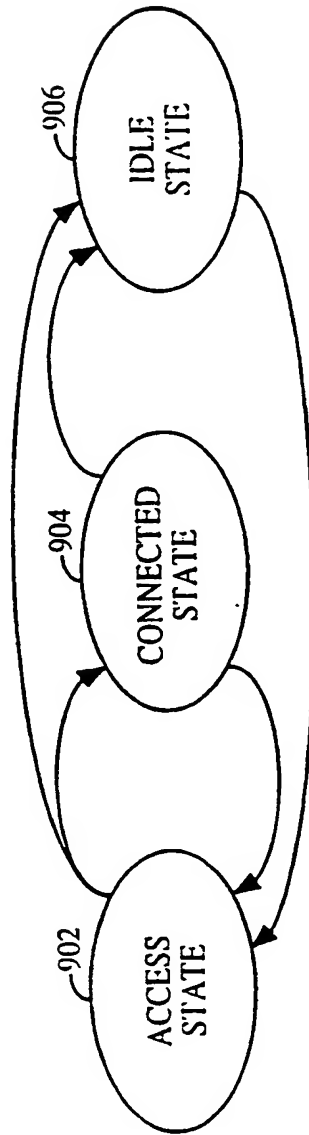


FIG. 9



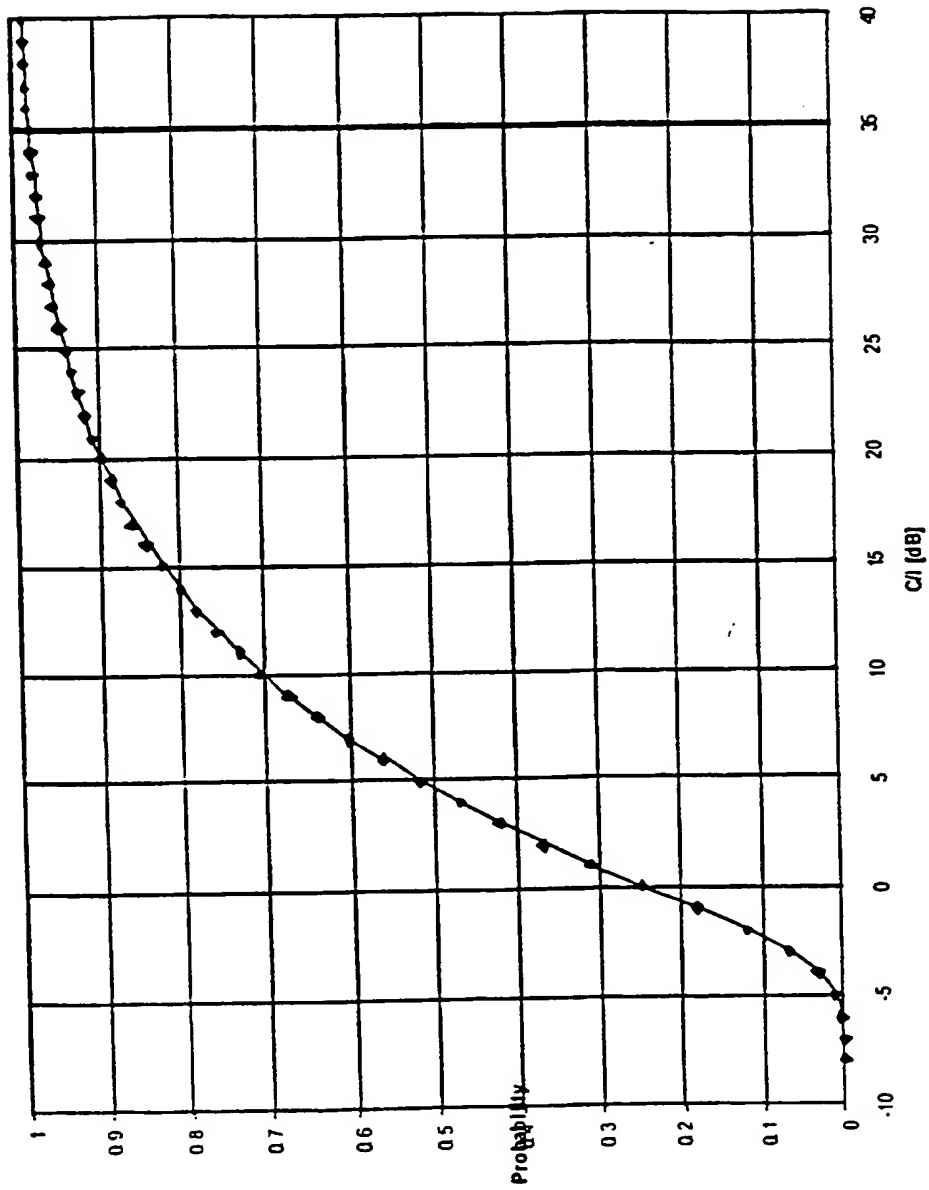


FIG. 10

REFERENCES CITED IN THE DESCRIPTION

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